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Astronomy

AMERICA'S BEST-SELLING ASTRONOMY MAGAZINE

December 2001

AMERICA'S NEW MARS STRATEGY

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Astronomer Sees

Great NEW Space Images
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and San Francisco

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LX200

MEADE®

A NEW WORLD STANDARD

Primary mirror lock; rigidly locks primary mirror in fixed position

4-speed zero image-shift microfocuser; operates through Autostar II hand controller

Coarse manual focus knob

Internal battery compartment; accepts eight C-cells and powers telescope for 40 hours

R.A. lock

R.A. manual slow-motion control

Diffraction-limited EMC super multi-coated optical system

Declination lock

Declination manual slow-motion control

Autostar II hand controller mounts on tiltable holder

Control panel with 7 connector ports, including two RS-232 serial interface ports

Patents pending on Autostar Easy Align, system architecture, and GPS alignment procedure



New 2001-2002
Meade General Catalog!
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The largest-selling telescopes in the world. ■ A NASDAQ® company.
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Meade® LX200GPS: the most important advance in Schmidt-Cassegrain technology in ten years is here.

For the visual observer, the astrophotographer, the CCD imager: all the telescope you could possibly have imagined.

For the advanced amateur, new Meade LX200GPS telescopes offer absolutely state-of-the-art optical, mechanical, and electronic performance unmatched by any competing models. Standard-equipment features include:

Precision GPS Alignment: Telescope alignment is accomplished automatically using integrated true-level and North electronic sensors in combination



Autostar II accesses over 125,000 database objects.

with a 16-channel GPS receiver located in the left-hand fork arm. Magnetic declination compensation is designed into the software and automatically engaged. Just press the ENTER button on the Autostar II hand controller and watch as the telescope slews at 8°/second to its first alignment star. Competing GPS telescopes use a 12-channel receiver (resulting in slower and less reliable position acquisition), do not include any magnetic declination compensation, and can easily result in first-alignment-star errors of up to 20° or more.

Revolutionary new rear-cell systems designed for the advanced visual observer, astrophotographer and CCD imager — systems that enable new levels of precision in focusing in all applications and in image centering on CCD chips:

Primary Mirror Lock: Flip a knob located just above the manual coarse-focus knob and lock the telescope's primary mirror rigidly in place. Used in conjunction with the Zero Image-Shift Microfocuser (below) the primary mirror lock completely cancels any residual image shift while focusing during visual, photographic, or CCD imaging applications.

Zero Image-Shift Microfocuser: Now you can obtain the most precise image focus possible — truly to a microscopic level — during visual and astrophotographic applications, and, during CCD applications, simultaneously maintain precise image centration on even the smallest CCD chips. Included as standard equipment with all LX200GPS Schmidt-Cassegrain models, the Meade Zero Image-Shift Microfocuser operates at 4 different speeds from extremely slow to fast; the entire microfocusing operation is actuated

through the Autostar II handbox. Coarse manual focusing is effected through the telescope's manual focus knob.

Autostar II: The new Autostar II control system provided with LX200GPS models includes all of the features that made previous LX200 models the largest-selling serious telescopes in the world. In addition, Autostar II includes an expanded 3.5 Megabyte memory, permitting a greatly enlarged database of more than 125,000 celestial objects, a database that is immediately accessible on the Autostar II display. A partial listing of the Autostar II database:

Library	No. of Objects
New General Catalog (NGC)	7840
Index Catalog (IC)	5386
Messier Catalog (M)	110
Caldwell Catalog	109
Named Objects	227
Herschel Catalog	400
Abell Catalog of Galaxy Clusters	2712
Arp Catalog of Irregular Galaxies	645
Uppsala Galaxy Catalog	12,940
Morphological Catalog of Galaxies	12,939
General Catalog of Variable Stars	28,484
SAO and Hipparcos Star Catalogs	31,090

SPECIFICATIONS: 7", 8", 10", and 12" LX200GPS — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; primary mirror lock; 4-speed zero image-shift microfocuser; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5 Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 9-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 125,000-object onboard celestial software library; 12VDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords are available for powering from auto cigarette lighter plug or from 115VAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

INTRODUCTORY PRICES MEADE LX200GPS

SCHMIDT-CASSEGRAIN TELESCOPES

8" LX200GPS	\$2495
10" LX200GPS	2995
12" LX200GPS	3995

7" LX200GPS Maksutov-Cassegrain . . **2995**

Packing & shipping charges in the 48 states: 8" — \$105; 10" — \$145; 12" — \$215; 7" — \$125. Prices shown are suggested U.S. national mail-order retail prices.

Scheduled Delivery: October, 2001.

A COMPARISON OF GPS SCHMIDT-CASSEGRAIN TELESCOPES

	Meade LX200GPS	Competing 11" GPS*
GPS Receiver	16-channel	12-channel
Magnetic declination compensation	yes	no
True-level electronic sensor	yes	no
Primary mirror lock	yes	no
Zero image-shift microfocuser	yes	no
Maximum slew speed	8°/second	3°/second
Memory	3.5-Meg flash	1.0-Meg flash
GO TO pointing precision	2-arcmins	unstated
High-precision pointing mode	yes; permits GO TO pointing precision within 1-arcmin	no
Permanent Periodic Error Correction	yes, both axes	one axis only; second axis unprogrammable
Object database	125,000 objects	"40,000+"
Encoder resolution	0.10 arcsecs	0.26 arcsecs
Internal battery compartments for battery powering	yes; batteries located internal to fork arms	no
RS-232 software download	yes; object libraries and software downloads available	not currently available on factory website**
Tracking calibration	not required	recommended after changes in telescope position or load

*Based on sample and instruction manual received in 7/01. ** As of 9/15/01.

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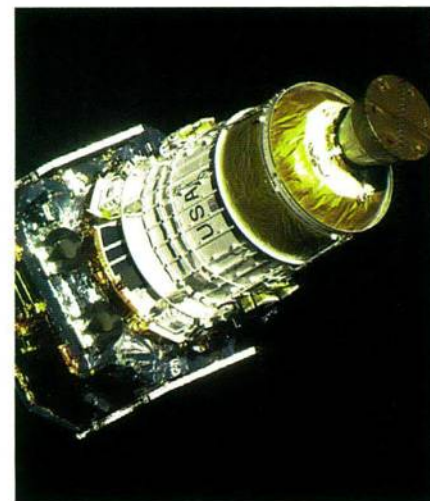
Chesley Bonestell's dramatic paintings gave many people their first taste of what distant planets and the far universe might look like. *Andrew S. Fazekas*

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High in the northern sky on autumn evenings, the King and the Lizard play host to some of the sky's best star clusters and emission nebulae. *Tom Polakis*

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From *The Glorious Constellations*,
© 1991; Harry N.
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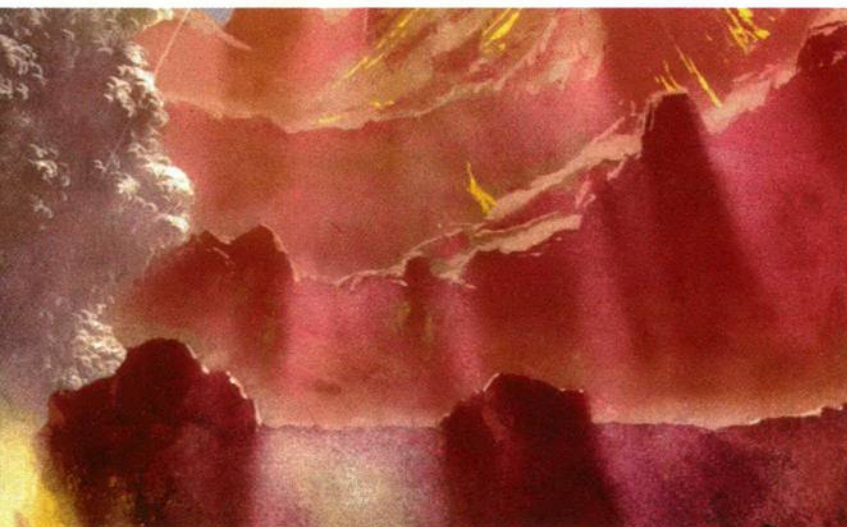
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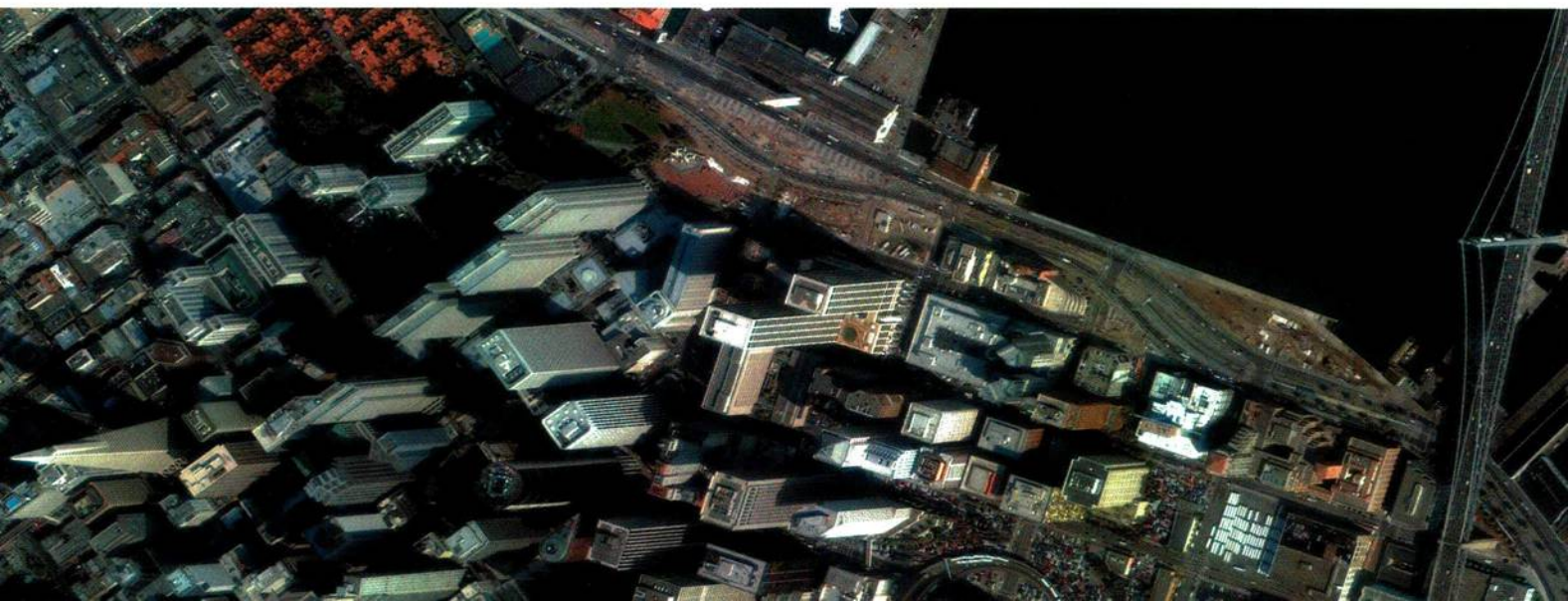
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64 Sky Show

Jim Pfeifferberger

Survivor and an Artist



In this issue we planned to present four pages of Earth images from the IKONOS satellite, but it turned out that the high resolution photos of Mecca and the pyramids were so good we just had to extend our coverage (see page 50). On the day we

decided to expand our IKONOS story, we got the press release from CBS television network's *Survivor* proclaiming that IKONOS had spotted the secret base camp which will serve as the location for the upcoming African edition of that megaserie. We all sighed mightily and thought "oh no," but then decided, why not have some fun with the satellite? It is, after all, a commercial enterprise, not one paid for with tax dollars.

So here we have the one-meter resolution image of the *Survivor: Africa* contestant tribal camp taken by Space Imaging's IKONOS satellite on August 13, 2001. According to the website "Survivor Maps," the tribal camp is located in the Shaba National Reserve in central Kenya. It is a Maasai-style village of 10 thatched huts fenced with thornbush.

IKONOS travels 423 miles above Earth's surface at a speed of 17,500 miles an hour. The 1,600-pound satellite was launched in September 1999 and is operated by Space

Imaging in Denver, Colorado. For more IKONOS photos of the *Survivor* location you may visit this online site: <http://www.spaceimaging.com/gallery/survivor/survivor.htm>.

We also are using this holiday issue of *Astronomy* to reintroduce the father of space art, Chesley Bonestell (see page 84). Bonestell practically invented the form with his imaginative oils and acrylics. We have excerpted a brief piece of a new biography of Bonestell and are accompanying this with six glorious color pages of images from his work.



Spaceimaging.com



Cedric Braun

The CBS *Survivor: Africa* contestant tribal camp was captured by Space Imaging's IKONOS satellite in August. Chesley Bonestell was one of the world's first great space artists.

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LX90

MEADE®

8"

LX90

LX90

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THE TELESCOPE OF A LIFETIME

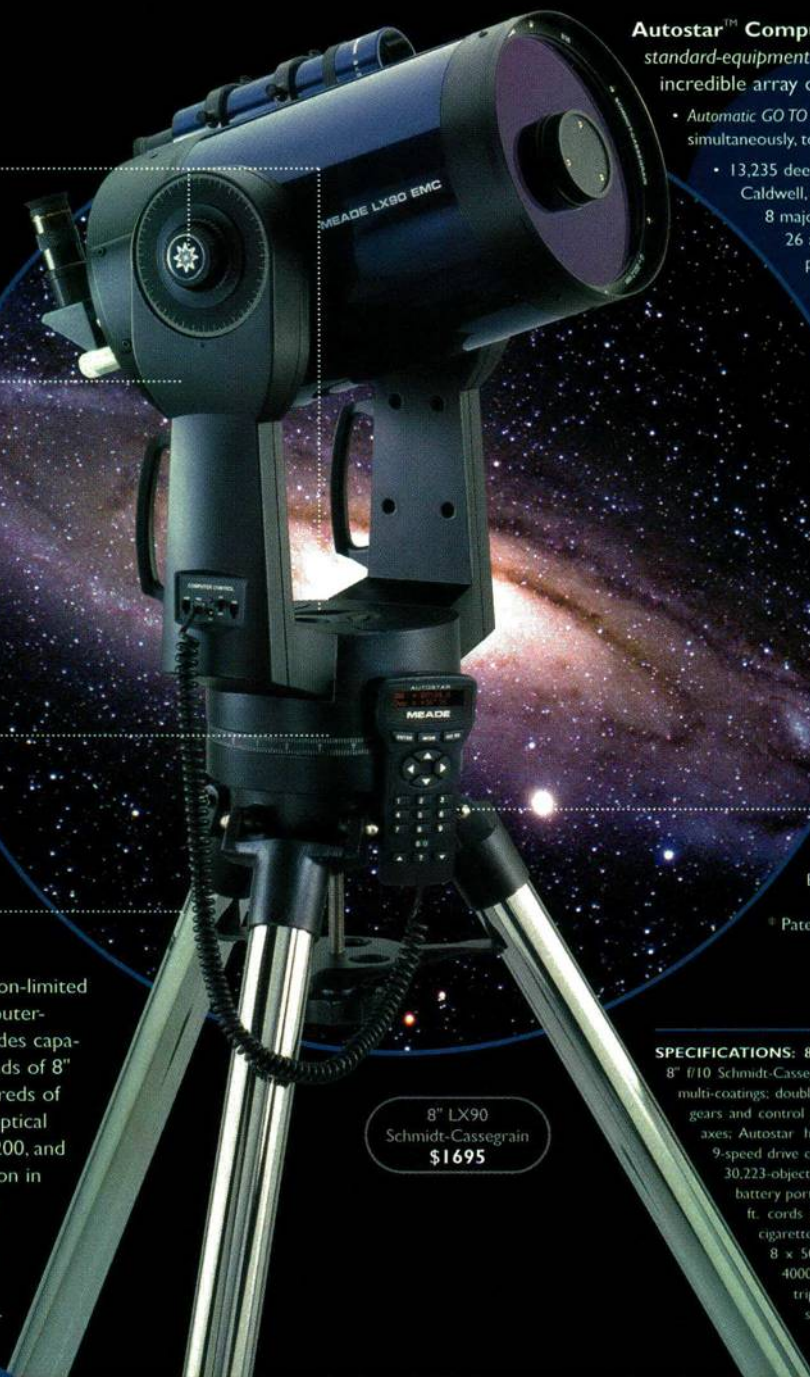
Worm gears of 4.9"-diameter on both telescope axes for smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging.

Die-cast-aluminum double-time fork mount that rigidly supports the optical tube in all sky orientations.

The LX90 is powered by C-cell batteries. Alternately, the telescope may be powered from an automobile cigarette lighter plug or from a standard 115vAC home outlet, using optionally available power cords.

Rigid chromed-steel variable-height field tripod — the same tripod provided with Meade LX200 models.

The Meade 8" LX90, with diffraction-limited Meade optics in an Autostar computer-controlled telescope system, includes capabilities not available on other brands of 8" Schmidt-Cassegrains costing hundreds of dollars more. Incorporating the optical system and coatings of the 8" LX200, and with 5 arc-minute pointing precision in the GO TO mode, the LX90 is an instrument fully qualified for long-exposure CCD imaging and astrophotography as well as for other advanced photo-visual applications.



Autostar™ Computer Controller: The LX90's standard-equipment Autostar controller permits an incredible array of telescope features:

- Automatic GO TO capability at 6.5"/sec on both axes, simultaneously, to 30,223 database objects, including:
 - 13,235 deep-sky objects — the complete Messier, Caldwell, IC, and NGC catalogs; 16,888 stars; the 8 major planets; the Moon;
 - 26 asteroids; 15 comets; 50 Earth satellites; plus 200 user-defined memory locations.
- Automatic GO TO capability to any object of known R.A. and Declination. Plus hundreds of special event menus, guided tours, utility functions, and telescope status options.
- Nine selectable slew speeds: 6.5"/sec, 3"/sec, and 1.5"/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- Control of the telescope through your personal computer. (Requires optional #505 Connector Cable Set.)
- Fast alignment of the telescope using any of three alignment functions, including the Meade-proprietary Easy Align®.
- Autostar is fully upgradeable over the Internet: add the positions of new comets, update the positions of Earth satellites, even add new software.

* Patent pending

8" LX90
Schmidt-Cassegrain
\$1695

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings; double-time fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plossl 26mm eyepiece; standard field tripod; operating instructions. **\$1695**. Packing & shipping in the 48 states: \$95.



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LXD55

MEADE

6"

8"

10"

SCHMIDT-NEWTONIANS WITH AUTOSTAR®

Now you can buy a Meade Schmidt-Newtonian telescope with Autostar dual-axis GO TO drive system for as little as \$599, complete!



Shown: Meade 8" f/4 LXDS5 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System

MEADE LXDS5 SCHMIDT-NEWTONIAN TELESCOPES

Shipped complete per specifications below:

6" LXDS5 Schmidt-Newtonian	\$599
8" LXDS5 Schmidt-Newtonian	729
10" LXDS5 Schmidt-Newtonian	879

Packing & shipping charges in the 48 states: 6" – \$75; 8" – \$85; 10" – \$95. Prices shown are suggested U.S. national mail-order retail prices.

SPECIFICATIONS: 6", 8", and 10" LXDS5-Series Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; all-metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXDS5 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.



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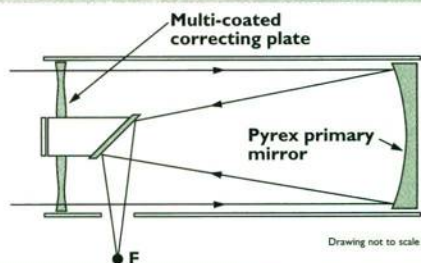
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Every Meade LXD55-Series Schmidt-Newtonian telescope includes this listing of standard equipment:

Schmidt-Newtonian optical systems: Manufactured entirely at the Meade Irvine facility, LXD55 diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Combined with fast f/4 (8", 10") or f/5 (6") optics, the standard-equipment Super Plössl 26mm eyepiece yields an actual field in excess of 1.3°, for brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images



The Meade Schmidt-Newtonian Optical System.

reveal subtle detail often lost in telescopes of lesser optical resolution. The optics are mounted in machined aluminum cells fitted to white-enameled metal tubes; each tube accepts the giant Meade

rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces.

LXD55 Equatorial Mount: Designed by Meade engineers and manufactured of machined aluminum for high-performance photo-visual observing, the new Meade LXD55 mounting moves effortlessly across the skies in either tracking or automatic GO TO modes. Included is an illuminated polar viewfinder for quick, precise polar alignment.



All LXD55 telescopes include an illuminated polar alignment finder as standard equipment.

Autostar Dual-Axis Electronic Control System: A revelation of advanced electronic and software design, the exclusive patent-pending Meade Autostar system, included as standard equipment with every LXD55 telescope, permits an amazing range of capabilities never before offered on telescopes in this price and aperture class:

Automatic GO TO capability at 4.5°/second on both axes simultaneously, to 30,223 database objects, including:

13,235 deep-sky objects — galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs.

16,888 stars sorted by name, SAO catalog numbers, double and variable stars.

50 objects in the Solar System; 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets.

50 Earth satellites; 200 memory locations for user-defined objects.

Automatic GO TO capability to any object of known R.A. and Declination.

Nine selectable slew and slow-motion speeds: 4.5°, 3°, and 1.5°/sec, 128x, 64x, 16x, 8x, 2x, and 1x sidereal.

Automatic sidereal-rate tracking in R.A. keeps objects precisely centered in the field.

Control of the telescope through your PC and full upgradability over the Internet, using the RS-232 serial interface. (Requires optional #505 Connector Set.)

Battery Pack (12vDC): Included with each LXD55 telescope; rests on the telescope's accessory shelf and plugs into the control panel. The battery pack accepts eight (user-supplied) D-cell batteries, which power the telescope for more than 40 hours.

Astrophotography and CCD imaging: Armed with their fast photographic speeds, Meade LXD55 Schmidt-Newtons are ideally suited for deep-space astrophotography and CCD imaging at the telescope's prime focus.



The LXD55 control panel is located below the upper bearing of the polar axis.

Meade LXD55 Schmidt-Newtons open up the skies to images and capabilities previously unavailable in telescopes of their aperture and price level. Consider what a Meade LXD55 telescope can do for your observing program:

6" LXD55 — Observe *hundreds* of galaxies, nebulae, and star clusters of all types *your very first night out*, and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope moves effortlessly and automatically from major planet to asteroid to galaxy to nebula at 4.5°/second, placing every object in the center of the telescopic field. Study fine fault lines on the Moon, structural detail in Jupiter's cloud belts and Red Spot, the Cassini division in Saturn's rings, and much more.

8" LXD55 — With 78% more light-gathering power than the 6" model, the 8" LXD55 roughly triples the number of observable objects in deep-space and resolves extremely fine planetary detail as well: Jupiter's cloud belts are seen as a web of intricate discontinuities; transits and shadow transits of Jupiter's main satellites are observable; six of Saturn's satellites may be seen in revolution about the planet. Deep-space phenomena take on new character with the larger 8" aperture, as Autostar moves the telescope automatically from one spectacular object to the next. CCD images at the telescope's prime f/4 focus show a new level of resolution and detail after only a few minutes' exposure.

10" LXD55 — A quantum leap in image brightness and resolution, the 10" LXD55 provides for a lifetime of serious study in deep-space or within the Solar System. Use Autostar to take an automatic tour, on any given evening, of, say, the 200 brightest diffuse nebulae, spiral galaxies, and globular star clusters. Or, with Autostar's pushbutton electronic slow-motion controls, scan the surface of the Moon at high magnification. Let Autostar locate and center in the field the outer planets Uranus and Neptune, now visible as finite-sized orbs, or Pluto, at the telescope's very limit of observability. It is an uncommon observer who might outgrow the capabilities of the Meade 10" LXD55.

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LXD55

MEADE®

ACHROMATIC REFRACTORS WITH AUTOSTAR®

Complete with LXD55 mounting, diffraction-limited optics, and Autostar controller — as little as \$695!

Multi-Coated Achromatic Lenses: With objective lenses that resolve to the theoretical limits for their apertures, Meade 5" and 6" LXD55 refractors present all of the diffraction-limited optical performance obtainable from the classical 2-element achromat design. Lunar, planetary, and deep-space images are rich in resolution and contrast, with a minimum of chromatic aberration.

LXD55 Equatorial Mount: Both refractors incorporate the Meade LXD55 mounting for smooth, effortless sidereal-rate tracking in R.A. or for automatic dual-axis GO TO operation at 4.5"/second with the standard-equipment Autostar hand controller. Precision worm gears on both axes assure low-backlash operation at all nine Autostar speeds. A 12vDC battery pack rests on the telescope's accessory shelf and operates either instrument for over 40 hours from eight (user-supplied) D-cell batteries.

Autostar Dual-Axis Electronic Control System: Locate any of 30,223 celestial objects in the Autostar database — automatically — at a push of the GO TO button. See the Meade LXD55 Schmidt-Newtonian ad on the preceding page for further details on Autostar capabilities.

Observing with a Meade 5" or 6" refractor is an experience unlike that with other telescopes, as the refractors' large unobstructed clear apertures enable a level of resolution and high contrast normally reserved for larger instruments of other types.

5" LXD55 — Study hairline lunar detail at high magnification as you range over the surface of the Moon using Autostar's pushbutton slow-motion controls; observe structural detail in Jupiter's cloud belts and Red Spot; resolve dusky markings on Saturn, as well as the Cassini division. Explore over 30,000 of Autostar's database objects, or any object of known R.A. and Dec., as the telescope moves automatically at 4.5"/second to locate and center each object.

6" LXD55 — The Meade 6" LXD55 refractor, with 44% more light-collecting power than the 5" model, permits a much wider imaging capability. Deep-space objects, from bright galaxies like Andromeda (M31) to faint nebulae like NGC 6559 in Sagittarius and thousands of other galaxies, nebulae, and star clusters in between, take on added brightness and resolution of form and structure. Significantly increased detail is visible on the Moon and planets: resolve craterlets in the floor of Plato, observe discontinuities in the ice cap on Mars; study changing patterns in Jupiter's cloud belts.

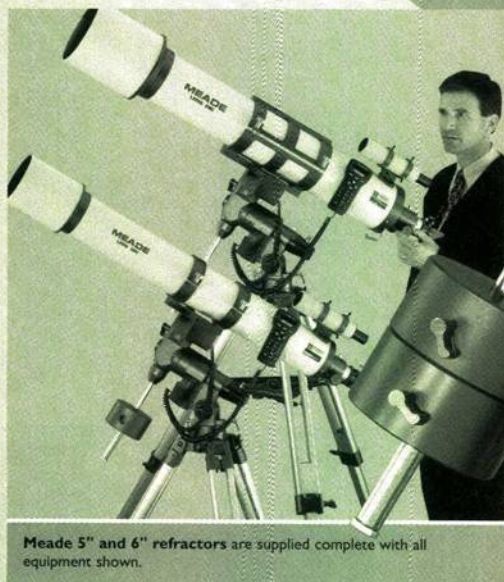
Shown: Meade 6" f/8 LXD55 Achromatic Refracting Telescope with standard-equipment Autostar Control System

MEADE LXD55 REFRACTING TELESCOPES

Shipped complete per specifications below:

5" LXD55 Achromatic Refractor \$695
6" LXD55 Achromatic Refractor 895

Packing & shipping charges in the 48 states: 5" — \$85; 6" — \$95. Prices shown are suggested U.S. national mail-order retail prices.



Meade 5" and 6" refractors are supplied complete with all equipment shown.

SPECIFICATIONS: 5" and 6" LXD55-Series Achromatic Refractors — Each complete telescope includes 5" f/9 or 6" f/8 achromatic refractor optical tube assembly with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm achromatic viewfinder; all-metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

P H C T O R

MEADE

XTE IMAGING SYSTEMS

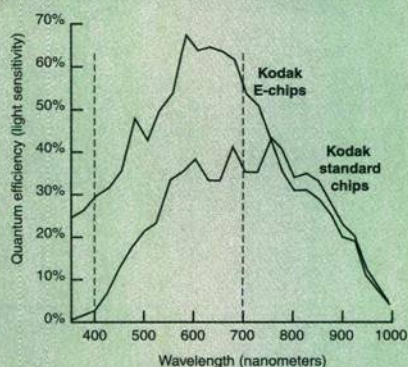
THE REAL CCD REVOLUTION IS HERE

How to cut all of your CCD exposure times in half!

New Meade Pictor™ 416XTE and 1616XTE imaging systems include the revolutionary Kodak E-Series of blue-sensitive CCD chips, permitting dramatically improved imager performance. With twice the overall light sensitivity and *four to ten times* the blue-light sensitivity of previous Kodak KAF-0400 and KAF-1600 chips (see graph below), the E-chips incorporated into Meade XTE-series imagers nonetheless maintain the previous chips' low readout noise and dark current characteristics, as well as their high-resolution 9.0-micron-square pixel dimensions.

All Meade Pictor CCD models are fully compatible with the 32-bit operating platforms of Windows 95, 98, ME, and NT, enabling fast, stable, smoothly-running program operation.

Use a **Meade XTE-Series imager** on your 6" or larger telescope and obtain imaging results that



Kodak E-chips used in Meade XTE imagers result in greatly increased light sensitivity. In this graph the region of visible wavelengths (400nm. to 700nm.) is indicated by dotted lines.

match or exceed the photographic results of many observatory telescopes. And, notwithstanding the enormous data-collection power of Pictor 416XTE and 1616XTE imagers, each system's standard-equipment SCSI interface enables full-frame download to the host computer in *seconds*, permitting virtually real-time object acquisition, focusing, and centering. On-board programs include automatic exposure level, dark current exposure, and flat-field sequence, in addition to pixel binning.

Meade Pictor 416XTE and 1616XTE models are a revelation of high-speed imaging performance on telescopes of all types and apertures. Applied to Meade LX200 Schmidt-Cassegrain telescopes,



The Meade Pictor 416XTE imaging system, shown with #778 Off-Axis Guider, Image-Orientation Adapter, and Pictor 201XT Autoguider.

imager operation and performance are extended still further, with advanced features such as Autocentering, Autofocus, and Automosaicking.

The Meade CCD Equipment System, provided at no additional charge with every Pictor 416XTE and 1616XTE, includes essentially all hardware and software required for advanced CCD imaging applications: **Pictor 201XT Autoguider**, for automatic guiding of the CCD camera during long-exposure imaging; **#778 Off-Axis Guider**, with adapters for use with either Schmidt-Cassegrain telescopes or with standard 1.25" eyepiece-holders; **CCD Image-Orientation Adapter** for precise orientation of the image on the CCD chip; and **Meade Epoch 2000ip Image Processing Software**, professional Windows-based image



The Meade CCD Equipment System is included as standard-equipment with Pictor 416XTE and 1616XTE imagers.

processing for the enhancement and analysis of CCD images — all packed in a foam-lined carrying case that provides for secure storage of the CCD camera and all items of the CCD Equipment System.

Optimized Tricolor Imaging with the New Pictor 616 Color Filter System

Recent performance improvements in the Meade Pictor 616 Color Filter System are as remarkable and dramatic as advancements in Meade XTE imagers. The new tricolor filter set includes red, green, blue, and clear filters with CAD-optimized



Meade Pictor 616 Color Filter System (left), shown attached to Pictor 416XTE Imager.

multi-layer dielectric interference coatings deposited on optical-flat substrates, permitting extremely sharp filter bandpasses and improved color balance. Filter transmissions exceed 90%, a more than 35% improvement, while simultaneously providing complete (< 1%) out-of-band blocking across the entire spectral sensitivity range of Kodak E-series CCD's.

MEADE XTE IMAGING SYSTEMS

- Pictor 416XTE** (16-bit), with Meade CCD Equipment System **\$1995**
- Pictor 1616XTE** (16-bit), with Meade CCD Equipment System **6495**
- Pictor 616 Color Filter System**, for use with Pictor 416XTE, 1616XTE **695**



**New 2001-2002
126-page
Meade General
Catalog!**

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your free copy.**

MEADE

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössl

52° field; multi-coated



Meade 4-element Super Plössl, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössl (SP; 4-elements; 1.25"; 52°):
 6.4, 9.7, 12.4, 15, 20, 26mm each: **\$79.95** (4.54)
 32mm (52°); 40mm (44°) each: **99.95** (5.26)
 56mm (52°; 2°) **199.95** (7.02)

Series 4000™ Ultra Wide Angle

84° field; multi-coated



The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)—4.7mm: \$169.95 (5.26); **6.7mm: 199.95** (5.26); **8.8mm (1.25"/2"): 239.95** (7.02); **14mm (1.25"/2"): 299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/Field Flatteners

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/8.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%; for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.



\$129.95 (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"



\$47.95 (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.



\$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"



\$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory, with 1.25" eyepiece adapter. #930: Same as #929 but with 2" barrel to fit into focuser with 2" eyepiece-holders.



#929 or #930, each: **\$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify #927 (.965"), #928 (1.25"), or #931 (fits .965" focuser, accepts 1.25" eyepieces).



\$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyepiece and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. Internal batteries included.



Bullseye reticle, 1.25"
\$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

\$129.95 (5.26)



Series 4000 Photo-Visual Color Filters (1.25")—Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **\$14.95** (2.73)
 Set #1—4 filters: #12, #23A, #58, #80A **49.95** (4.54)
 Set #2—4 filters: #11, #25A, #47, #82A **49.95** (4.54)
 Set #3—4 filters: #8, #21, #38A, #56 **49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **\$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.



\$49.95 (5.26)

Electric Focuser for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.



#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **\$149.95** (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery. **\$169.95** (7.88)



#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.



\$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.



\$79.95 (5.26)

Series 4000™ Super Wide Angle

67° field; multi-coated



For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)—13.8mm: \$139.95 (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm (2"): 239.95** (7.02); **40mm (2"): 299.95** (7.02)

Series 3000™ Plössl

50° field; multi-coated



Meade Series 3000 Plössl yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössl's, Meade Series 3000's are multi-coated for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm (far right in photo), an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössl's yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössl's (4-elements; 1.25"; 50°)
 5, 6.7, 9.5, 16, 25mm each: **\$49.95** (3.86); **40mm (44° field): \$79.95** (3.86)



Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B—Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)
 #910B—Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)
 #911B—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)
 #908N—Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)
 #910N—Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)
 #911N—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)



Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X—Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)
 #910X—Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)
 #911X—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to less than one second. A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three: **\$49.95** (6.85)



MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". Batteries included. **\$99.95** (3.45)
 As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **\$79.95** (5.26)



Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately. **.965": \$27.95; 1.25": \$29.95** (3.86)



Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **\$39.95** (3.86)



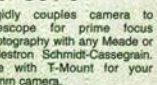
Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-Mount for your camera. **\$39.95** (3.86)



T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera. **\$26.95** (3.86)



CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with *any* brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helioid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexure between the CCD and telescope." — Jack Newton



#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **\$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-10; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)



**Series 4000™
f/3.3 CCD Focal
Reducer/Field
Flattener**

Revolutionary 3-element Meade design permits ultrafast CCD imaging with increased edge-of-field resolution and color correction. Reduces CCD exposure times by up to 80%. Threads on the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to f/3.3 and f/6.3 SCT's to f/2. Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **\$149.95** (5.26)

**Plossl 25mm Illuminated Reticle
CCD Framing Ocular**

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror (above). Includes 4-element coated Plossl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **\$129.95** (4.54)



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only \$149!

Epoch 2000sk (upper display at left): Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields smaller than one arc second! With star positions displayed as precisely as 0.01 arc second, the Trapezium in Orion is no longer shown as a single point, as in other software, but as four precisely oriented starpoints, just as they appear in the telescope. No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field and updates R.A. and Dec. instantaneously as the cursor is moved about the field. Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field to a precision of 30 arc seconds, routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software (lower display at left): Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95. **\$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM. **\$179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk. **\$25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95. **\$199**

**MA12mm Illuminated Reticle
Astrometric Eyepiece**

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **\$119.95** (4.26)

**Series 4000™
8mm – 24mm
Zoom Eyepiece**

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing, even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **\$219.95** (6.38)

**#825 8 x 25mm
Right-Angle Viewfinder
for ETX-90**

Permits comfortable right-angle viewing. Replaces standard equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helioid focusing. **\$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **\$34.95** (3.86)

**#932 45° Erecting
Prism for ETX®**

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **\$49.95** (3.86)

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

- #670 for ETX-60/70... **19.95**
- #673 for ETX-90... **24.95**
- #675 for ETX-105... **27.95**
- #678 for ETX-125... **29.95**

**ETX® Deluxe
Field Tripod**

#884: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 90° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumb-screws. Includes custom-fitted carry bag (shown) with pocket for accessories. **\$199.95** (10.00)

**ETX® Hard
Carrying Cases**

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

- #774 Case for ETX-90 models: **99.95** (8.58)
- #776 Case for ETX-105EC: **99.95** (8.58)
- #775 for ETX-125EC: **149.95** (13.38)

ETX® Carry Bag

Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories. **\$36.95** (5.26)

**Electric
Focusers
for ETX®**

Meade-engineered for smooth, rapid focusing with any ETX model. Four-speed operation from coarse to fine. Standard equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus ETX/EC models through the telescope's hand controller.

- #1244 Electric Focuser for all ETX-90 and ETX-105 models: **\$119.95** (6.85)
- #1247 Electric Focuser for ETX-125 models: **\$119.95** (6.85)

**Advanced Field
Tripod for ETX-125**

#887: Yields rock-solid stability for sensitive applications of the ETX-125, even at high magnifications. Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125. Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport. **\$349.95** (14.00)

**Tripod Adapter
for ETX-125**

Included with the #887 Tripod (above), the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications. **#889 Adapter: \$69.95** (7.70)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in () next to each price. The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:

- ASTRONOMICS, Norman, OK.**
Orders: 800-422-7876; Info.: 405-364-0858.
- FOCUS CAMERA, Brooklyn, NY.**
Orders: 800-221-0828; Info.: 718-436-6262.
- LUMICON, Livermore, CA.**
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sky Gem

Death Becomes Beauty

Smoke-like tendrils of the 5,000-year-old Veil Nebula (NGC 6960, NGC 6992-5) supernova remnant mark the perimeter of a massive star's cosmic grave.

Spawned from the still-expanding supernova blast wave (moving upward in the HST frame), this braided gem glows from shock-induced heating of interstellar material.

NASA/ESA/Digitized Sky Survey
(Caltech)

The Amazing Hans Bethe



Thanks for Adam Frank's wonderful story, "Probing the Birth of Starlight" (September 2001). Hans Bethe is truly an amazing

physicist, and it is obvious that he loves his field. Why else would he be publishing scientific papers well into his nineties?

It reminds me of the story involving the 1948 scientific paper by George Gamow, Ralph Alpher, and Hans Bethe, in which they proposed the theory of creation of the elements. The authors whimsically arranged their names to read "Alpher, Bethe, Gamow." And so the theory was referred to as the "alpha-beta-gamma theory" — until proved incorrect by Margaret Burbidge, Geoffrey Burbidge, William Fowler, and Fred Hoyle. They incorporated the idea into the Big Bang model of the formation of the universe. — *Scott Zillmer, Washington, D.C.*

I enjoyed the Bethe article. I had always thought that the late Fred Hoyle, not Hans Bethe, was responsible for the theories of how stars shine. Please delineate and contrast the contributions of these two great astronomers in a future issue. — *John Ackerman, Doylestown, Pennsylvania*

Additional Listings Needed

It's hard to argue with the 25 top astronomers of all time as listed in the 2002 edition of *Explore the Universe*. However, another astronomer who definitely fits into the sequence of discoveries that helped formulate our understanding of the universe is Henrietta Swan Leavitt (1868–1921) of Harvard College Observatory.

Leavitt discovered a direct relationship between the apparent magnitudes and the periods of Cepheid variables. By 1917, her work resulted in a precise mathematical relationship between a Cepheid's brightness and its period.

Edwin P. Hubble used the results of Leavitt's work as the "standard candle"



Henrietta Swan Leavitt discovered the relationship between the period and luminosity of classical Cepheids. *Astronomical Society of the Pacific*

to determine the distance to galaxies — which resulted in his determination that the universe was expanding.

Also missing from the list are those who used radio astronomy, or infrared, ultraviolet, and x-ray studies to greatly expand the spectrum of astronomical observations. I nominate Arno Penzias and Robert Wilson for their discovery of the cosmic background radiation.

To keep the list at 25, I leave the difficult task of removing a listed name to *Astronomy*. — *Leland Langston, Colorado Springs, Colorado*

Hans Bethe should have been included in the top 25 astronomers list. Discovering how stars shine was an important addition to astronomy. — *Janette Conan, Abbotsford, British Columbia, Canada*

Inside Palomar

Thanks for a fascinating inside look at Palomar Mountain Observatory's Hale Telescope ("Keepers of the Night," September 2001). And thanks to all of those who, over the years, kept this engineering marvel competitive

and productive. The 200-inch Hale is the Yankee Stadium of telescopes; there are newer, bigger, and better, but none are as cool. — *James Williams, Stockton, California*

Familiar Differences

In "Ask Astro" (September 2001), Athena Andreadis's answer to what extraterrestrial life might resemble begins with, "It's almost certain that extraterrestrial life won't look anything like what we find on Earth, and it is absolutely certain that we won't find humanoids out there."

I would be amazed if most extraterrestrial life was much different from Earth's organisms. We have a wide variety: some creatures have two, four, six, or eight legs, while most mollusks move around on one pseudopod.

There are centipedes and millipedes, as well as sessile animals and plants. Earth also boasts lichens and birds and microorganisms and elephants. These creatures are covered with chitin, skin, scales, feathers and fur. It's also hard to beat chlorophyll and leaves. Even humans (two legs, two arms, one head) work very well in our example of intelligent species. So, how different could extraterrestrial life really be? — *Bud Skinner, North York, Ontario, Canada*

Where in the World is JPL?

On page 34 of "Is There Life Under the Ice?" (August 2001), author Dana Mackenzie states, "In 2001, of course, the Europa Orbiter is still a dream — merely drawings on the whiteboards of the Jet Propulsion Laboratory (JPL) in Pasadena, California."

My beef is that JPL is not in Pasadena. It's entirely within the city limits of La Cañada Flintridge (LCF). Before LCF was incorporated, Pasadena was merely the nearest city, which claimed JPL as its own.

More than any other institution, JPL has contributed to the flood of knowledge recently acquired about our

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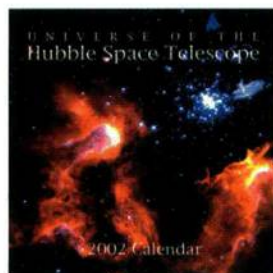
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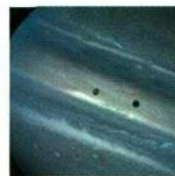
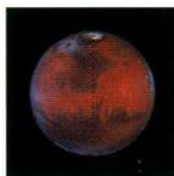
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A TALKING BACK

solar system, a fact about which LCF (not Pasadena) is justifiably proud. — Lee Simpson, Walnut, California

NASA's Jet Propulsion Laboratory property is split between the municipalities of Pasadena and La Cañada Flintridge (LCF). JPL's east parking lot is in Pasadena, while the rest of the facility is indeed in LCF. The association with Pasadena is due to the vagaries of history and the U.S. Postal Service.

In the 1930s, rocket scientists from Caltech (in Pasadena) moved their experiments from the campus to the uninhabited Arroyo Seco. Within a few years, the Arroyo Seco experiment site grew into a facility needing a mailing address — decades before LCF was incorporated in the 1970s. It was natural to maintain the Caltech/Pasadena association at that time.

No formal request has been made by LCF to change JPL's mailing address. And, the smaller LCF post office would have a hard time handling the volume of mail generated by JPL. — Steve Edberg, Jet Propulsion Laboratory

Corrections

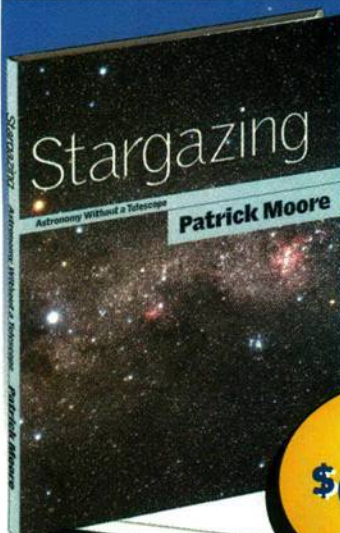
The September 2001 Hans Bethe article mentions University of Rochester physicist Robert Marshak on page 40. The correct spelling of his last name is "Marshak." — Ron Adams, Rochester, New York

The photo credit for "Eclipse Start to Finish" on page 114 of the May 2001 "Hot Shots" section should have read Phil Rau. Our apologies to Mr. Rau. — Astronomy editors

In "Behind the Scenes" (September 2001), John Dobson was identified as a former Buddhist monk. In fact, he was a monk in a Vedanta monastery, part of the Ramakrishna religious order. — Astronomy editors

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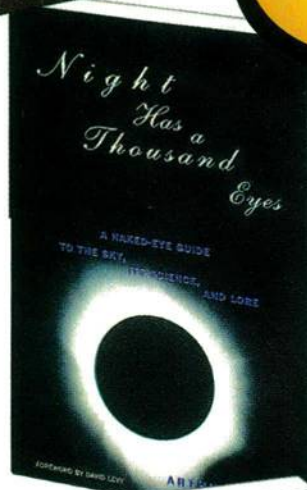
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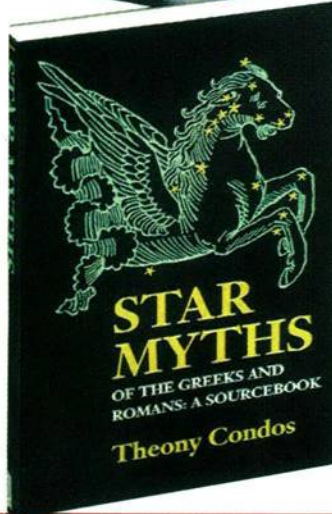
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GALACTIC NEIGHBORHOOD

Black Hole on the Loose

► Two-and-a-half billion years before the sun was more than a glimmer in the galaxy's eye, the fates of a distant black hole and its plump stellar companion were already sealed — to wander the galaxy alone, never resting in their high velocity and highly eccentric orbit. Now, seven billion years later, the pair has entered the galactic vicinity of our solar system like a traveling history lesson, to provide a glimpse of the galaxy before it ever was.

An international team of astronomers reported in the September 13 issue of *Nature* that a wandering microquasar system 6,000 light-years from Earth called XTE J1118+480 is zipping by the sun at 90 miles per second (145 kilometers per second). Armed with knowledge that the black hole component of XTE J1118+480 harbors more than seven times the mass of the sun and that its stellar companion has been consumed to the point that only one-third of a solar mass remains, the team is confident that the system is an ancient galactic remnant. Moreover, the system was likely born from one of the galaxy's first starbursts, an era which produced large stars and stellar remnants.

"The star that preceded this black hole probably formed in a globular cluster even before our galaxy's disk was formed," says Felix Mirabel, an astrophysicist with the Institute for Astronomy and Space



Physics of Argentina and the French Atomic Energy Commission. "What we're doing here is the astronomical equivalent of archaeology — seeing traces of the intense burst of star formation that took place during an early stage of our galaxy's development."

Astronomers using the Rossi X-ray Timing Explorer spacecraft in March 2000 discovered XTE J1118+480. Since then, the microquasar (powered by the energy released as the black hole devours mass from its companion) has been found on old photographic plates and in numerous optical and radio observations. But this latest collaboration of Brazilian, Argentine, American, and European astronomers, armed with the National Science Foundation's Very Long Baseline Array radio telescope, was the first to accurately discern the position, trajectory, and speed of the cosmic passersby.

Globular clusters are compact spherical concentrations of hundreds of thousands of the oldest stars populating the galaxy. They are believed to have been among the first objects to



form in the galaxy, so their orbits about the galactic center often take them on highly eccentric trajectories outside the galactic plane. What's more, recent numerical simulations strongly hint at the possibility that the most massive stars and their remnants are regularly ejected from these geriatric clusters altogether.

That's exactly what Mirabel and his colleagues — among them National Radio Astronomy Observatory astronomer Vivek Dhawan — believe happened to XTE J1118+480, which now orbits the galactic center on a path similar to those of the globular clusters. After sifting through old Palomar Observatory Sky Survey photographic plates taken 43 years apart, the team was able to track the microquasar through time and space. And with the help of researchers at the Space

A black hole in the microquasar XTE J1118+480 cannibalizes material from its companion (above). The system's orbital path (top, red line) over the past 230 million years has brought it close to the sun (yellow circle).

Telescope Science Institute, they digitized the photographic data to retrieve the orbital trajectory of the vagabond system. "This is a great example of applying multiple tools of modern astronomy — telescopes covering different wavelengths and digital databases — to a single problem," adds Dhawan.

According to Mirabel and his team, there might be thousands of such wandering objects whizzing about the galactic center — each playing out a destiny similar to that of XTE J1118+480. And they can't wait to get back out there and find some more.

— WILLIAM SCHOMAKER

I. Rodrigues and I. F. Mirabel, NRAO/AUI/NSF

LOCAL GROUP

A Cannibal in Our Midst

▶ Anyone who has gazed through a telescope at autumn's showpiece deep-sky object, the Andromeda Galaxy (M31), has seen its two companion galaxies. The dwarf ellipticals M32 and NGC 205 join with Andromeda in what seems like a tranquil scene: They all have celebrated billions of birthdays and move so ponderously that they appear immobile. Yet looks can be deceiving.

The southwestern portion of M31 poses for a new camera on the 8-meter Subaru Telescope. A new study shows M31 is devouring its two companion galaxies.

What doesn't show at first glance is the unbridled hunger of M31. This massive galaxy is ripping stars off its dwarf companions, the first course in a repast that will see M31 totally devour them. An international team of researchers led by Rodrigo Ibata of the Strasbourg Observatory in France has discovered a stream of stars in the halo of M31 that have been stripped from M32 and NGC 205. They reported their results in the July 5 issue of *Nature*.

The Andromeda Galaxy ranks as the largest galaxy in our Local Group. It contains about twice as many stars as the Milky Way — itself the second largest member of the group — but otherwise appears quite similar. Now that similarity appears to extend to their voracious

appetites: Astronomers have known for years that our galaxy has cannibalized its smaller neighbors. (The current meal is being provided by the Sagittarius dwarf galaxy.) Telltale streams of stars — the remnants of the galaxies it has swallowed — thread through the Milky Way's halo. "This has given the outskirts of our galaxy a rather lumpy structure," says Ibata. "We wanted to see if Andromeda's halo was the same."

The researchers used the 2.5-meter Isaac Newton Telescope, located on La Palma in the Canary Islands, to make the most sensitive panoramic survey yet of the Andromeda Galaxy. They took 50 long-exposure digital images and then pieced together a panorama of one side of the galaxy. The cannibalized stars appear as a distinct stream and have a slightly different chemical composition from other stars in the halo. By viewing the individual stars and measuring their speeds, the researchers expect to be able to map the distribution of dark matter in the halo for the first time.

M31 currently lies about 2.2 million light-years from the Milky Way, but that won't last forever. The two are falling toward each other at a speed of about 300,000 miles per hour (500,000 km per hour). It will take a few billion years, but the two galaxies will inevitably meet.

"Colliding with a dwarf galaxy is only like having a cream pie hit your windshield," says team member Geraint Lewis of the Anglo-Australian Observatory. "When our galaxy and Andromeda collide, it'll look like a car crash — very messy." — RICHARD TALCOTT

GALILEO MISSION

Callisto's Odd Landscape

▶ If you notice someone with spiky hair as you're walking down the street, odds are it belongs to a young person. But the solar system seems to be making a different fashion statement. At least among the moons of Jupiter, it turns out that a spiky landscape of bright ice and dark dust resides on the oldest surface. Even more surprising, the landscape shows signs of slow but active erosion.

The new results come from images returned by the Galileo spacecraft after its close flyby of Callisto on May 25, 2001. Galileo swooped to within about 86 miles (138 km) of the surface, yielding the highest resolution view ever of any jovian moon. The best images show craters as small as 10 feet across (about 3 meters).

"We haven't seen terrain like this before," says James Klemaszewski of Academic Research Lab in Phoenix, Arizona. "It looks like erosion is still going on," adds the surprised researcher who, along with David Williams and Ronald Greeley of Arizona State University, has been processing and analyzing the Callisto images.

Callisto orbits farther from Jupiter than the planet's three other large moons and its surface is more heavily cratered than any other moon in the solar system. The geologically dead world shows no obvious signs that it experienced any volcanic activity or tectonic movement. Such geological processes have



Subaru Telescope, NAOJ

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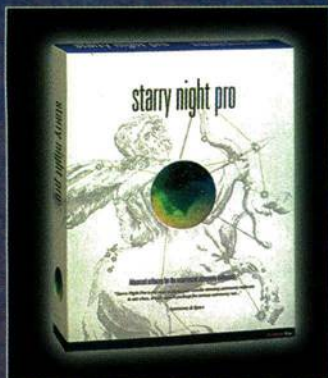
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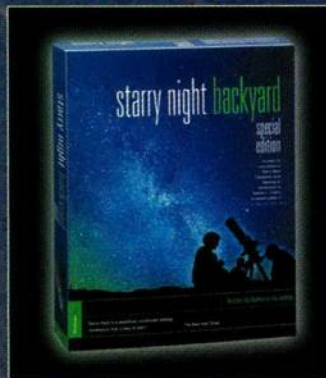
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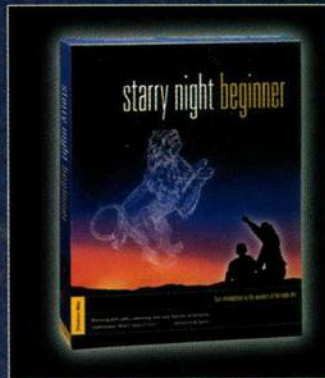
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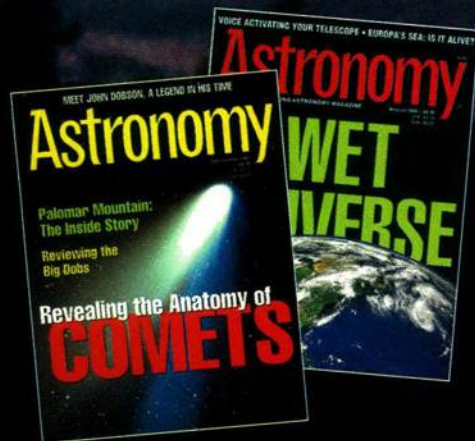
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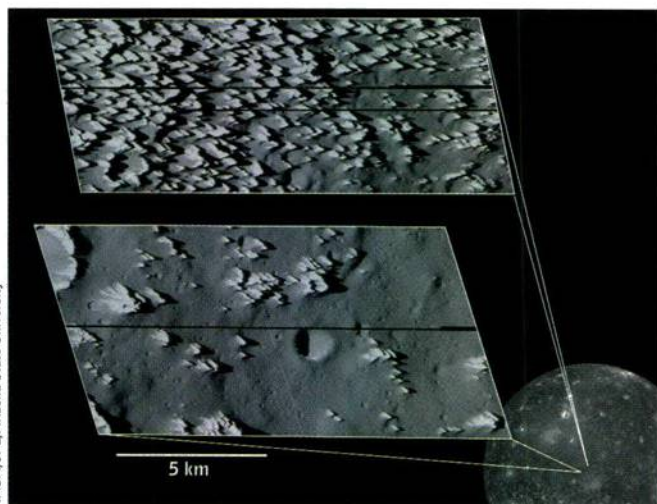
erased some or all of the impact craters on Jupiter's three inner moons — Io, Europa, and Ganymede.

The jagged hills seen in the new images may be icy material that was thrown out during a huge impact billions of years ago, or

Galileo's most recent images of Callisto show details only 10 feet across (below). The spiky terrain in the upper inset appears unique, while the lower inset shows eroded terrain. Galileo also returned the first global color image of Callisto (bottom).

perhaps the highly eroded remains of a large impact structure. Each of the bright peaks is surrounded by darker dust that appears to have slumped off the peak. The spires rise about 260 to 330 feet (80 to 100 meters) above the surface.

"They are continuing to erode and will eventually disappear," says Klemaszewski. Planetary scientists don't yet understand what drives the erosion. One theory suggests that as the ice sublimates and turns directly to vapor, it leaves



NASA/JPL/Arizona State University



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GEMINI TELESCOPE



Gemini Observatory/Colin Aspin

DEEP INSIDE A MOLECULAR CLOUD, a massive young star sheds a huge cloud of gas and dust. The star, saddled with the designation AFGL 2591, lies more than 3,000 light-years from Earth in the constellation Cygnus. The star possesses at least 10 times the mass of the sun and shines more than 20,000 times brighter, yet it would be invisible to an optical telescope. This image was made with an infrared camera attached to the 8-meter Gemini North Telescope on Mauna Kea. Infrared radiation easily passes through the dust and gas in the molecular cloud, giving a clear view inside. The nebula emanating from the star probably started expanding a few thousand years ago; it has already grown to more than 500 times the size of the solar system. Although similar outflows occur frequently in sunlike stars, they are rare in ones this massive.

behind the dust that was bound up in the ice. The accumulating dark material may also absorb enough of the sun's heat to warm the adjacent ice and keep the process going.

Since Galileo arrived at Jupiter six years ago, it has completed more than 30 orbits of the giant planet. After each one, it returns observations of Jupiter and its moons to Earth. Following the May flyby of Callisto, on August 6 Galileo flew over the north pole of volcanically active Io. Images and magnetic readings from that encounter were still being analyzed as *Astronomy* went to press. — R. T.

SPACE EXPLORATION

MirCorp Plans Space Station

▶ To soar above the clouds, the stratosphere, the mesosphere, and to observe the stars and planets unhindered by the damnable turbulence and opacity of Earth's atmosphere — this is the stuff of every backyard observer's dreams. And now, officials with Amsterdam-based MirCorp have announced that this longtime fantasy may soon become a promising and profitable reality.



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With current plans to develop the world's first private space station, dubbed Mini Station 1, the commercial space development pioneer MirCorp could be ready to take wannabe space travelers into orbit as early as 2004. (The corporation is perhaps best known for leasing Russia's ailing Mir space station in February 2000.) The September 5 announcement comes hard on the heels of an historic agreement between the Russian aerospace giant RSC Energia (MirCorp's major shareholder) and the Russian space agency Rosaviakosmos.

According to MirCorp representatives, Mini Station 1 will have a projected lifetime of more than 15 years and will be designed to carry three passengers for 20 days at a time. Though MirCorp has not yet released detailed plans for the station — or expected fares — they believe that it can be successfully deployed for a modest \$100 million. What's more, by placing the corporate space hotel in an orbit similar to that currently occupied by the International Space Station (ISS), MirCorp's Soyuz transport vehicles can be used jointly by Mini Station

An artist's conception shows the proposed Mini Station 1, a commercial venture that could ferry three passengers into low-Earth orbit for 20 days at a time.



MirCorp

HUBBLE SPACE TELESCOPE



NASA and the Hubble Heritage Team (STScI/AURA)

A MASSIVE BURST OF STAR FORMATION transforms the spiral galaxy NGC 3310 in Ursa Major into a blazing beacon. A team of astronomers led by Gerhardt Meurer of The Johns Hopkins University are using the Hubble Space Telescope to perfect a technique to untangle the history of starburst activity in galaxies. Several hundred star clusters with up to a million stars each trace the spiral arms of NGC 3310. These clusters, which appear as bright blue diffuse objects in this image, become redder as they age because their hot, blue, massive stars burn out quickest. By measuring the colors of the various clusters in the image, the researchers found that the stellar groupings range in age from about one million up to more than 100 million years. That implies that the starburst began more than 100 million years ago, perhaps when another galaxy collided with NGC 3310.

1 and the ISS. MirCorp president Jeffrey Manber says that such cooperation, financed by commercial profits, will help the Russian federation to fulfill its commitment to support the ISS.

"MirCorp's Mini Station 1 agreement creates the first commercial space infrastructure — offering multiple flight opportunities under our control to a destination that will be fully supported by the private sector," says Manber.

MirCorp's past experience with commercial space customers includes signing the first commercial space-flight contract with California millionaire and premiere space tourist Dennis Tito in June 2000. Before the Russian government decided to dump Mir into the South Pacific earlier this year, Tito was scheduled to live aboard the station. Instead, he was successfully ferried to the ISS in a Soyuz spacecraft last April. — W. S.

COSMOLOGY

Through a Cluster, Darkly

▶ It's just a bunch of hot air. Yet, in this case, it just might help solve one of the enduring riddles of cosmology — the distribution of the universe's dark matter.

Using NASA's Chandra X-ray observatory, a team of astronomers from the Institute of Astronomy at



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Cambridge University in England has detected huge clouds of hot gas roiling in the hearts of several massive galaxy clusters.

Relying on prior data and images obtained from the Hubble Space Telescope and the Canada-France-Hawaii telescope atop Mauna Kea, the Cambridge team selected a sample of five of the largest known galaxy clusters, which lie at distances ranging from 1.5 billion to 4 billion light-years. The astronomers aimed Chandra at the clusters to soak up their x-ray emissions, resulting in what amounts to high-temperature portraits, or maps, of these gigantic objects.

"The temperature maps can be used to determine the mass needed to prevent the hot gas from escaping these clusters," explained Cambridge University's Steven Allen at September's "Two Years of Science with Chandra Symposium" in Washington, D.C.

That this gas remains trapped within these clusters, despite the lack of visible mass to gravitation-

ally bind it there, has given the scientists ample reason to think much of it is ensnared by surrounding, yet invisible, material.

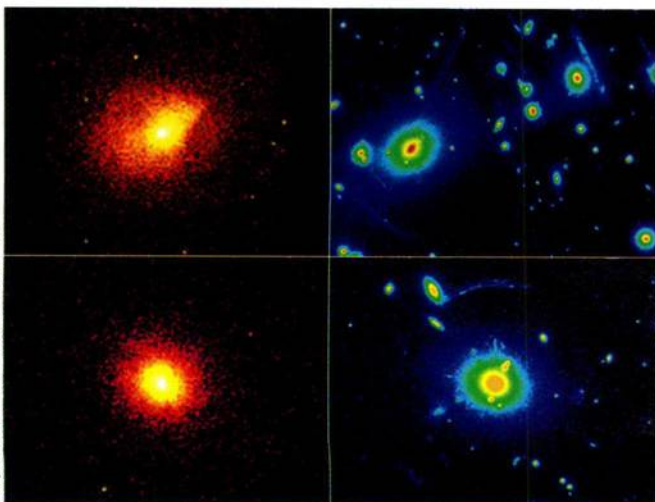
"We found that the stars in the galaxies and hot gas together contribute only about 13 percent of the mass of the total cluster," said Allen. "The rest must be in the form of dark matter."

Astronomers have recently assumed that most of the universe's matter is part and parcel of this dark, elusive stuff. And since it reveals itself only indirectly by gravitational influences on visible matter, pinpointing its presence has proven extremely tricky.

The nature of dark matter has been hotly debated. But a growing consensus among astronomers is that it is formed by a curious elementary particle that abets gravity with its mass but only weakly engages normal, so-called baryonic, matter. Ironically, scientists have dubbed these particles WIMPs (Weakly Interacting Massive Particles), which belies their true strength on the universal stage.

Because galaxy clusters encompass huge chunks of real estate, they offer a good model of the universe as a

X-ray (left) and optical images (right) of two galaxy clusters in the Cambridge survey.



X-ray: NASA/IOTA/S. Allen et al. Optical: HST

HUBBLE SPACE TELESCOPE



ESA and Valentin Bujarrabal (National Astronomy Observatory of Spain)

HIGH-SPEED GAS RAMS into the interstellar medium surrounding this proto-planetary nebula. The object, nicknamed the Calabash Nebula or the Rotten Egg Nebula (because it contains a lot of sulfur that would smell unpleasant if one could smell in space), lies some 5,000 light-years from Earth in Puppis. A cool, dying star at the nebula's center is ejecting prodigious amounts of gas in opposite directions at speeds up to a million miles per hour. The gas, colored yellow in this Hubble image, smashes into the interstellar medium. The collision creates shock fronts that heat the surrounding material (shown in blue). The gas flow apparently started about 800 years ago. Astronomers think that within another 1,000 years, the object will evolve into a fully developed planetary nebula, like a butterfly emerging from its cocoon.

whole. Given the team's finding of scant normal matter in this five-cluster sample, Allen claims that "we live in a low-density universe," which will only continue to expand.

Such a conclusion is consistent with recent studies of the cosmic background, distant supernovae, and the large-scale distribution of galaxies. The findings may also contribute to a more exacting measurement of the universe's total mass density. — PAUL MORLEDGE

PLANETARY SCIENCE

The Biggest Asteroid Yet

► Two hundred years after Giuseppe Piazzi discovered the first — and biggest — asteroid, astronomers have dethroned the champion. On July 2, 2001, a group of American astronomers led by Robert Millis of Lowell Observatory announced the discovery of a bright Kuiper

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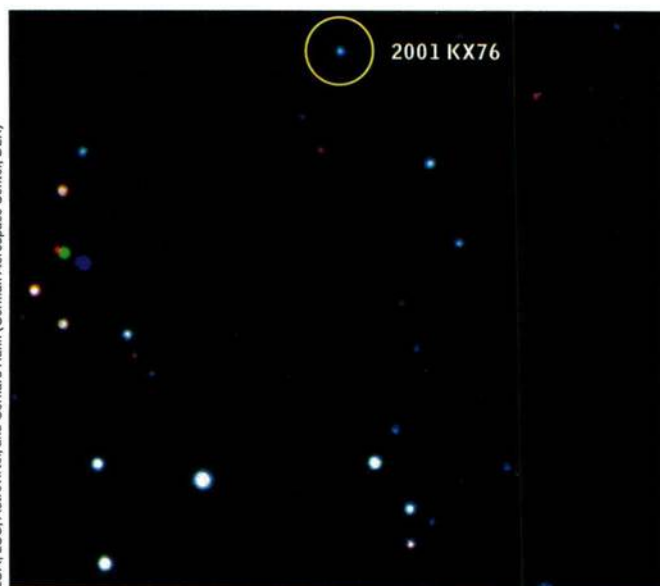
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The Kuiper Belt Object 2001 KX₇₆ boasts a diameter of at least 750 miles, making it the largest asteroid known in the solar system.

Belt Object, which was designated 2001 KX₇₆. Kuiper Belt Objects — icy asteroids that orbit the sun beyond Neptune — are relics from the formation of the solar system and among the most primitive objects known.

Astronomers suspected that 2001 KX₇₆ might be large because it looked bright, but they couldn't pin down its diameter without knowing how far away it was. To determine that, they needed to know the object's orbit, a difficult task when only a limited number of observations existed. Enter a team of German, Finnish, and Swedish astronomers, who used the world's first operational "virtual telescope" to automatically search through old photographic plates looking for previous sightings.

The effort paid off. The researchers found several plates containing faint images of KX₇₆, some dating back to 1982. Armed

with accurate positions, the team computed the first precise orbit for the asteroid. The object currently lies about 4 billion miles (6.5 billion km) from the sun, or some 43 times farther than Earth does.

To get a diameter for KX₇₆, the researchers had to estimate its albedo, or the percentage of sunlight it reflects. (They could then calculate the diameter from its observed brightness.) Assuming an albedo of 7 percent, matching that of a well-observed Kuiper Belt Object, Varuna, and about that of our moon, the diameter works out to about 750 miles (1,200 km). An albedo of 4 percent, typical of a comet nucleus, yields an even larger value of 875 miles (1,400 km). Former champion Ceres boasts a diameter of about 600 miles (950 km).

A diameter this big makes KX₇₆ about half the size of Pluto and slightly larger than Pluto's moon, Charon. It raises the likelihood that other objects yet to be discovered in the outer solar system may be similar in size to Pluto. — R. T.

Math Error Sparks Age Debate

In the March 2001 issue, we reported on breaking news from Cambridge University Egyptologist Kate Spence (see "Egyptian Error Proves Pyramid's Age," page 32). All evidence indicated that she had cracked the riddle of the orientation of the Great Pyramid of Khufu at Giza, which strays from perfect north-south alignment by only 0.05°. Spence's argument, based on the apparent use of two then-circumpolar stars (Zeta Ursae Majoris and Beta Ursae Minoris) and a plumb line to divine the direction of true north during simultaneous transits, appeared air-tight, yielding a construction date for the Great Pyramid of 2478±5 B.C. But just this summer, Dennis Rawlins, with *DIO, The International Journal of Scientific History*, and Keith Pickering, with Analysts International Corporation, revealed in *Nature* that Spence neglected to divide by the cosine of Giza's latitude to obtain the ground precession rate. This presents a fatal flaw in the analysis and may push back the construction date by 150 years or more.

Time to Name That Spacecraft

It's not a game show, but the winner will receive a free trip to Cape Canaveral. NASA is looking for help in naming its latest Great Observatory. Currently called the Space Infrared Telescope Facility (or SIRTf for short), NASA is searching for a friendlier name. The spacecraft will be the fourth and final cog in the Great Observatories program, which consists of the Hubble Space Telescope, the Chandra X-ray Observatory, and the recently defunct Compton Gamma-Ray Observatory. Contestants must write a short essay explaining the reasons for the suggested name. Names of current and proposed



Help NASA name its Space Infrared Telescope Facility.

missions are not allowed, nor are living people. To enter the contest, go to <http://sirtf.caltech.edu/namingcontest/>. The deadline for nominations is December 20, 2001.

M33 Harbors No Black Hole

Black holes seem to pop up in every galaxy, but a new study by David Merritt of Rutgers University and colleagues suggests that M33 in Triangulum harbors no supermassive black hole at its center. The astronomers used the Hubble Space Telescope to measure the speeds of the stars in M33's core and found that, if a black hole resides there, it can't have a mass of more than 3,000 solar masses.

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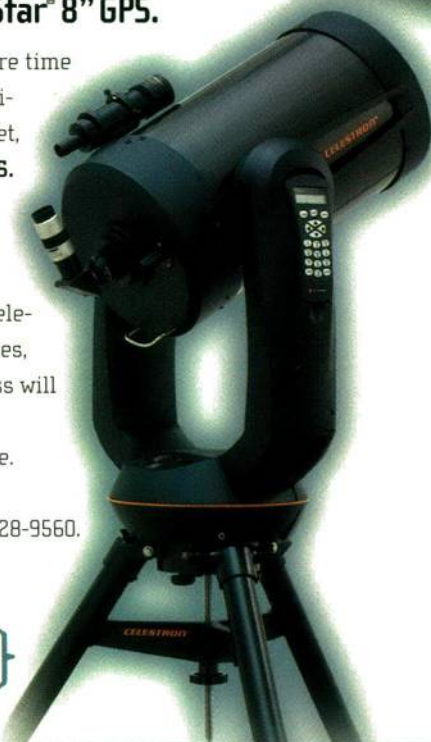


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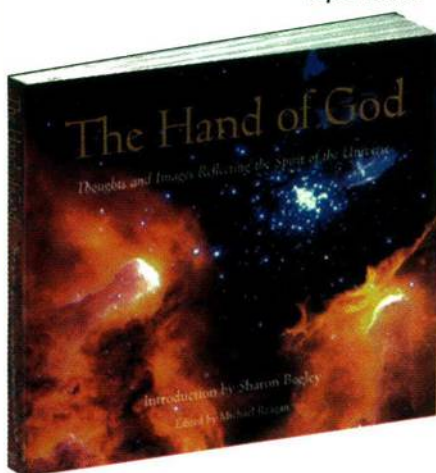
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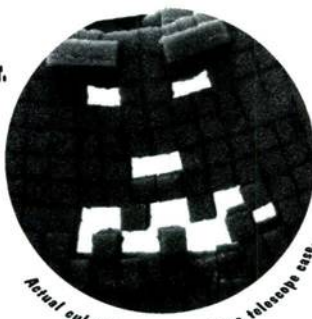
5. Halloween is over and your case continues to haunt you.

4. You like missing dark matter. JMI has removed 30% of the bulk & added wheels on the 8," 10" & 11" cases.

3. You need to get a handle on things - 10" and 11" case has 3!

2. Your not ready to get diced sliced and cubed.

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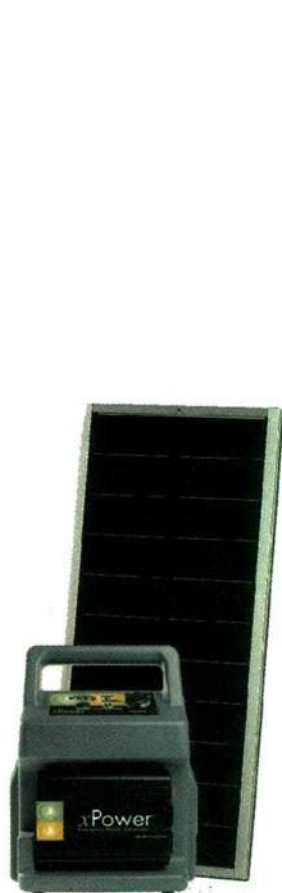
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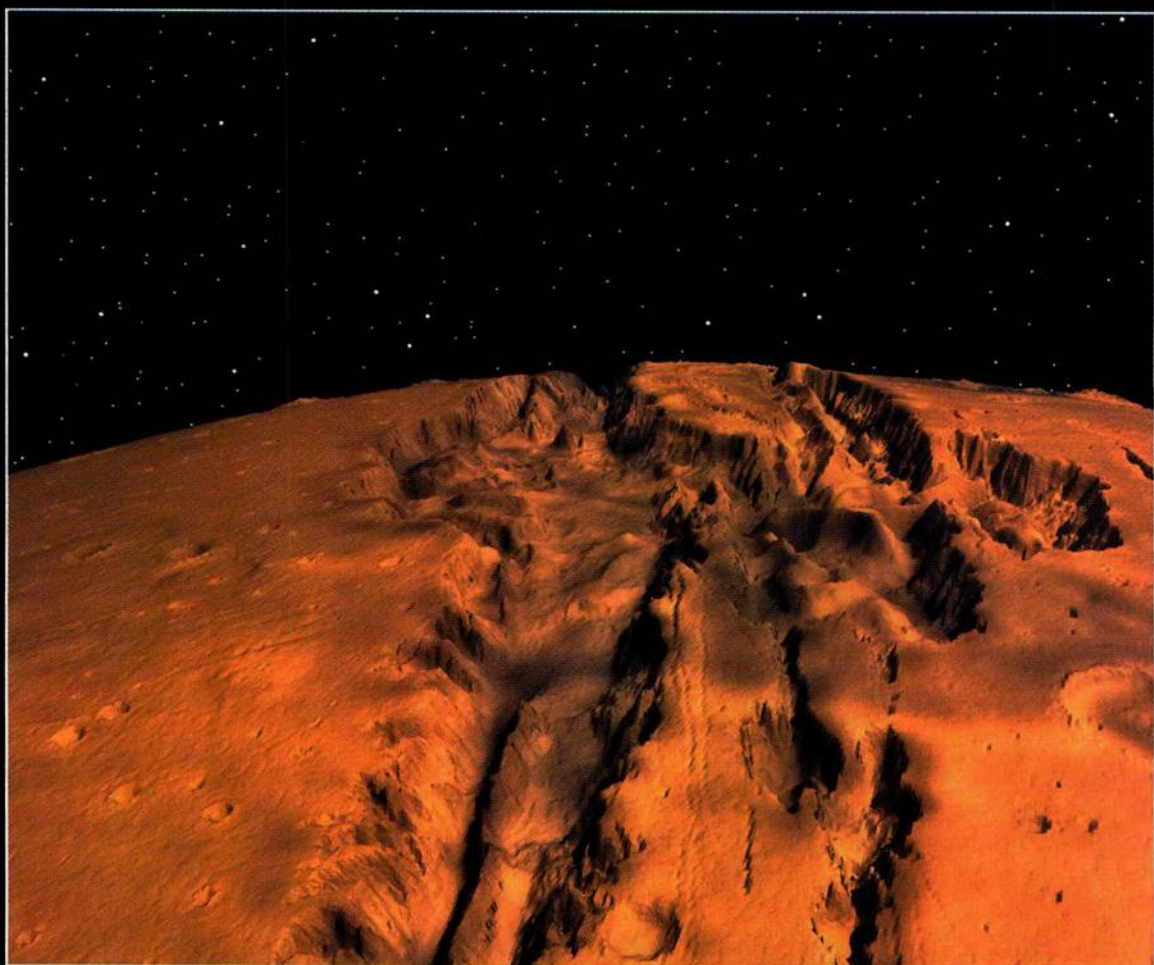
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LAUNCHING A CARA

The Red Planet has proved a mysterious and elusive subject. After mixed results in exploring this



VAN TO MARS

by Robert Zimmerman

distant realm, NASA is forced to rethink and restructure its approach to this alien world.

The date was Saturday, April 7, 2001. The sky was a perfect blue. On the launchpad, the Mars 2001 Odyssey probe sat atop a Delta-2 rocket, awaiting liftoff. Scheduled to reach Mars orbit in October, this probe's launch would initiate the return to flight of NASA's ambitious Mars program, following the embarrassing failures of Mars Polar Lander and Mars Climate Orbiter in 1999.

In the control room a mile away, Scott Hubbard, then Mars Program Director, watched intently as the countdown

A computer-generated image of Valles Marineris. NASA/JPL



wound down. A genial, clear-thinking man, he had arrived at NASA less than a year earlier with the difficult job of resuscitating the program. As he watched, the controllers scrambled to solve several minor problems.

Finally, at 11:02 A.M., the rocket roared skyward. Hubbard, however, did not yet relax. “The launch [alone] isn’t good enough,” he later said. At the press viewing area outside stood Jim Garvin, the Mars Program Scientist. Garvin, whose nonstop enthusiasm for Mars exploration can leave one breathless, could hardly contain his excitement as he watched the rocket rise upward. “I was elated beyond belief,” he remembers.

Next to him was his boss Ed Weiler, Associate Administrator for Space Science. Less emotional than Garvin, Weiler kept trying to calm him down. Later, after *Odyssey* had reached orbit, deployed its solar panels, and was functioning properly, Weiler suggested that Garvin — still overwhelmed with emotion — avoid the many post-launch

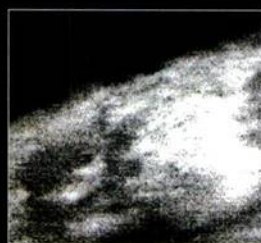
hemisphere large regions colored bluish-green — thought by some to be vegetation — would expand during the summer and shrink in the winter. In fact, over time the canals themselves seemed to change, suggesting to some the work of intelligent beings.

Most scientists scoffed at these conclusions, saying instead that the canals were merely optical illusions. As noted by German astronomer Kasimir Graff, objects as small as canals were unlikely to be visible “in that confusion of grayish, yellowish, and brownish shades of endless detail near the limit of visibility.”

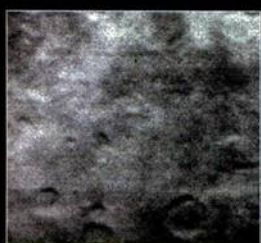
Yet, to the public at large, the evidence was tantalizing. Could Mars harbor life?

MARS IS DEAD

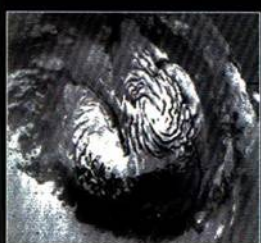
With the coming of rockets and space travel in the 1960s, the tools for getting a conclusive answer to this question finally seemed at hand. The first successful mission to reach



1965



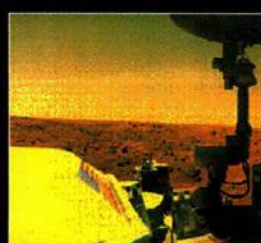
1965



1972



1976



1976

parties that were just then getting underway, and instead do something else to unwind.

The desire of these men to restrain their enthusiasm is not unlike that of almost every scientist and engineer involved in modern Mars exploration. “Mars keeps tricking us,” notes Garvin.

The history of Mars exploration has been fraught with arrogant misconceptions, false conclusions, and overly optimistic expectations. Each of these prejudices led to tragic errors which in turn prevented a thorough and candid look of that alien planet.

Only today, almost forty years after the first Mars mission, do scientists seem to be viewing Mars honestly. The result is a long-term American Mars program that is relentless, coordinated, and most importantly, open-minded. Or as Hubbard puts it, “We’re humbler now.”

MARS IS ALIVE

In 1877, Giovanni Schiaparelli aimed his telescope at the Red Planet and thought he saw a network of fine lines on its surface. He named these lines *canali*, Italian for channels or grooves. For English-speakers, the word was instead translated as “canals,” implying the existence of intelligent life with an ability to build artificial structures.

For the next ninety years this myth grew. Science fiction writers imagined a dying planet short of water in which an ancient race of aliens now desperately struggled to hoard and manage its dwindling water supplies. Some even took this fantasy one step further and imagined the martians invading Earth, attracted by our vast oceans and teeming life.

Other facts helped reinforce the belief that Mars had life. As the martian seasons came and went, astronomers could see the advance and withdrawal of icecaps. In the southern

Left to right: First ever close-up image of Mars taken by Mariner 4; First image, taken by Mariner 4, to show unambiguous evidence of heavy martian cratering, leaving scientists to believe the planet is moon-like and lifeless; Mariner 9 image of the planet’s north polar cap; Viking Orbiter 1 pictures the famous “Mars face”; Viking Lander 1 image of martian terrain near the landing craft.

Mars was the American Mariner 4 spacecraft. On July 15, 1965, Mariner 4 flew past Mars at a distance of 6,118 miles, taking 22 pictures of the changing dark southern regions.

To everyone’s disappointment, the images revealed a dead, moonlike planet, covered with craters. Combined with Mariner 4’s atmospheric data — which showed a much thinner and colder environment than expected — alien intelligent life seemed impossible. The vision of a planet inhabited by martians was officially dead. The so-called canals had been optical illusions.

Moreover, four years later — only three weeks after the Apollo 11 astronauts landed on the moon — two more American fly-by missions, Mariner 6 and Mariner 7, confirmed this bleak conclusion. More than two hundred photographs of the same southern dark regions that scientists still hoped contained surface vegetation once again showed Mars to be a harsh, moonlike planet.

Based on these three missions, scientists sadly concluded that Mars was a dead planet with no evidence of life. The project scientists for Mariner 6 and 7 also concluded that “it would seem unlikely that Mars ever experienced a terrestrial phase in which primitive oceans could have been present.”

MARS IS ALIVE, MAYBE?

Still, only about ten percent of the martian surface — all in the southern hemisphere — had been photographed. To

complete the planet's first global reconnaissance, on May 30, 1971, the United States launched Mariner 9, destined to become the Red Planet's first artificial satellite.

As Mariner 9 made its five and a half month journey toward Mars, earthbound telescopes noticed the appearance in the middle southern latitudes of what scientists called "yellow" clouds (named because they are most visible using a yellow filter). Soon, these clouds spread across Mars.

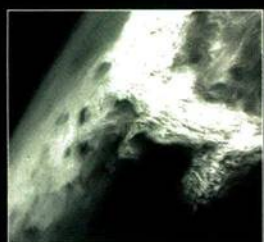
When Mariner 9 entered orbit on November 14, 1971, it discovered that the yellow clouds were actually a dust storm engulfing the entire planet and hiding its tantalizing surface. In order to save fuel, Mariner 9 was shut down to wait out the storm. By mid-December the storm had subsided enough so that Mariner 9 could begin taking pictures. What the spacecraft then saw, however, resembled nothing seen by the earlier Mariner spacecraft.

Scientists were first astonished to see four giant volcanoes jutting up through the haze, the first non-terrestrial volcanoes

more habitable for terrestrial micro-organisms than many had suspected possible." The next American Mars mission, Viking, thus focused on trying to answer this single question.

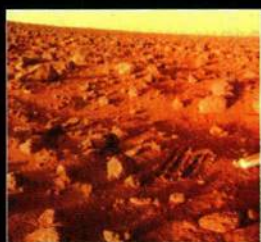
Viking was made up of four spacecraft: two landers and two orbiters. The orbiters would make a detailed photographic survey of the martian surface, with a greater resolution than Mariner 9. The landers were to search for evidence of organic life, using a television camera, a robotic arm and scoop for grabbing surface samples, and three separate experiments.

Despite over two dozen rock sample tests by both landers, scientists remained puzzled. While no organic material was detected, one experiment produced copious amounts of carbon dioxide, which a few believed to indicate the possibility of life. Most others concluded that the martian soil was lifeless, that chemical reactions explained the data. Because of this disagreement, however, the mission — whose primary purpose had been to find life on Mars — came to no conclusion.



1977

NASA/JPL



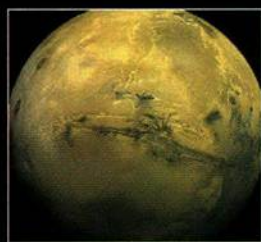
1977

NASA/JPL



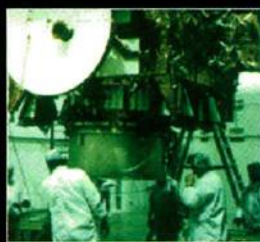
1978

NASA/JPL



1980

NASA/JPL



1993

NASA/JPL

Left to right: The first global dust storm observed by the Viking Orbiters; Viking 2 Lander close-up of the surface of the planet with trenches (middle of picture) dug by the lander's sampler instrument; Color mosaic of Viking Orbiter images showing Candor Chasma; Global mosaic of 102 Viking 1 Orbiter images of the rusty-looking planet; The billion-dollar Mars Observer spacecraft — NASA lost it in space.

ever discovered. The tallest, Olympus Mons, was seventeen miles high — three times higher than Mount Everest.

Then, east of the volcanoes, Mariner 9 spotted a martian canyon that made our Grand Canyon seem like a measly ditch. More than 2,500 miles long and 400 miles wide, this canyon, Valles Marineris, would cover the entire United States if transplanted to Earth. Here was a *canali* that would have made Schiaparelli blanch.

And those weren't the only surprises Mariner 9 revealed. Scattered everywhere were meandering channels reminiscent of Earth's river valleys. Though Mars did not seem to have any surface water, its geology suggested that liquid water had existed sometime in the past. In fact, the northern hemisphere, smooth and generally uncratered, was also lower in elevation than the cratered southern hemisphere. These facts implied that a large ocean once existed.

And the mysterious wave of annual darkening in the southern hemisphere? It was now recognized as nothing more than the annual dust storms of varying intensity.

MARS IS DEAD, MAYBE?

Once again scientists began speculating whether Mars might contain life, either now or in the past. "The data provided by Mariner 9," wrote Carl Sagan in the 1973 book *Mars and the Mind of Man*, edited by Ray Bradbury, "suggest that, at least in some times and some places, Mars may be much

MARS WAS ALIVE, ONCE, MAYBE?

After Viking's pessimistic results, the exploration of Mars withered away. For the next seventeen years no missions were launched to that bleak alien surface.

Slowly, however, interest in the exploration of Mars was rekindled. For one thing, scientists had many unanswered questions about the geology unveiled by both Viking and Mariner 9. What had caused the giant volcanoes? Had Mars ever been home to liquid water able to form the river-like channels? Was liquid water still present?

For another, the experiments from Viking were ambiguous enough to make many scientists entertain loftier questions, such as, could Mars have once harbored life? If so, was it still present on Mars?

Finally, in 1992, another American mission was sent aloft. Mars Observer, costing almost a billion dollars and carrying seven different sensors, was going to answer all the questions that scientists still had about Mars. As Ed Weiler remembers, Mars Observer — like Viking — followed "the old idea that every mission to the planets should be a mega-sized Battestar Galactica."

Instead, Mars Observer proved that big, expensive, all-encompassing space probes could be an awful waste of money. Three days before the spacecraft was scheduled to enter Mars orbit, all contact was lost. Though no one to this day is certain what went wrong, mission engineers theorized that a ruptured fuel line caused the spacecraft to spin out of control.

This costly failure — the first in the American planetary program in more than twenty years — caused a fundamental reassessment by NASA. The new mantra became "faster, better, cheaper," as articulated by NASA chief Dan Goldin. No longer would the space agency put all its research eggs

into one mission basket. Future Mars research would be scattered across several smaller missions.

The multiple mission approach — a kind of continuous caravan of American martian probes — has proven more successful. From 1997 to 1999, four missions — Mars Pathfinder, Mars Global Surveyor, Mars Polar Lander, and Mars Climate Orbiter — were launched for about the same cost of Mars Observer alone. And while each mission was far less capable than Mars Observer, and two were complete failures, the 50 percent success rate of these four missions produced 100 percent more data than Mars Observer.

In addition, by launching a convoy of missions NASA designers could quickly learn from both their successes and failures. For example, after the losses in 1999, Weiler, who took charge of NASA's space science in 1996, decided to reevaluate the program. At that time it was focused on achieving a Mars sample return mission as early as 2005. "The schedule was rushed, the budget was too tight, it was

management and budget, while Garvin, as Mars Program Scientist, coordinated the program's research goals.

Together these men restructured everything. Not only did they slow the pace — canceling the lander mission in 2001 — they rearranged the schedule so that later missions could more effectively use the knowledge gained from previous missions. Instead of sending both a lander and an orbiter every two years, the program now alternates orbiters with landers. The orbiters give scientists data with which they can fine-tune the landing missions two years later. In addition, the four-year gap between similar missions gives engineers time to redesign subsequent missions.

Mars 2001 Odyssey begins this new cycle. After reaching Mars orbit on October 24, 2001, Odyssey will spend the next ten weeks refining its orbit using both aerobraking and engine burns. If all goes well, by the beginning of 2002 it will reach a circular 93-minute polar orbit able to view the entire martian surface every two sols. For the next two and a half



1997

NASA/JPL



1997

NASA/JPL



1997

JPL/Malin Space Science



1998

JPL/Malin Space Science



1999

NASA/JPL

clear that people weren't talking to each other," says Weiler. The unrealistic schedule was creating so much pressure that it was doing more harm than good.

Weiler decided the program needed some overall coordination, and hired Hubbard and Garvin to provide it. As Mars Program Director, Hubbard took charge of the program's

Left to right: Mars Pathfinder images a martian sunset; The Sojourner rover samples the rock "Moe" with an x-ray spectrometer probe; Mars Global Surveyor (MGS) images a crater in the planet's southern hemisphere that shows signs of once having held a lake; MGS snaps a breathtaking picture of Olympus Mons, the solar system's largest volcano; The closest Mars Climate orbiter came to Mars (2.8 million miles).

A RUSSIAN-MARTIAN JINX?

It seemed a match made in heaven: the Red Communists and the Red Planet. With their ambitious space program, it seemed natural for the Soviets to conquer Mars.

Unfortunately, it hasn't worked out that way. After forty years and twenty attempts to reach Mars, the Soviets, and later the Russians, have scored an unenviable success rate of zero percent.

In the 1960s they tried eleven times. Every mission failed, with only three probes even getting into orbit.

Then, in 1971, both a Soviet lander and orbiter reached Mars in operating condition. Unfortunately, both probes were designed to work automatically, so they took their readings during the global dust storm that Mariner 9 simply waited out. The dust-shrouded images from both probes were useless.

In 1973 the Soviets tried again, sending an armada of four spacecraft to Mars. All failed because of a computer chip defect. Two missed the planet entirely, one failed right after orbit insertion, and the last landed but shut down after only 150 seconds on the surface.



The Soviet Mars 1 spacecraft during its construction in 1962. Soviet Space Agency

Fifteen years later, in 1988, the Soviets tried again with two probes, Phobos 1 and 2. Each carried a lander and an orbiter, with the landers aimed at the martian moon Phobos. Both failed in route to Mars, the second failing just minutes before reaching Phobos.

Finally, in 1996, the Russians built Mars 96. With an orbiter, four landers, and two penetrators to probe the ground, this ambitious spacecraft did not even make it past Earth orbit, its rocket exploding during launch. This sad failure pretty much ended

the Russian interplanetary space program.

Without a program, the Russians next put an experiment on Mars Polar Lander, the first time an American Mars lander carried Russian equipment. It also became the first American Mars lander to fail.

The Russians haven't given up, however. In 2003 the European Space Agency will use a Russian rocket to launch its Mars Express probe.

Keep your fingers crossed. Maybe this mission will finally end the Russian-martian jinx.

years it will use a multi-spectral camera and a gamma-ray spectrometer — similar to instruments used by Earth resource satellites like Landsat — to collect detailed geological and mineralogical data of the martian surface. “This first wave of reconnaissance will show us where on Mars we’ve got to go,” says Garvin.

NASA will then launch two identical lander/rover missions in 2003 to these locations. Each rover will have a 90-day lifespan and the ability to travel over 300 feet a day. As they move and take pictures, they will also use a robot arm, a multi-spectral camera, and a gamma-ray spectrometer to make a detailed study of the local geology.

Two years later, in 2005, it will be the orbiter’s turn again. Mars Reconnaissance Orbiter will use a high-resolution multi-spectral camera — capable of seeing objects as small as eight inches across — to zoom in on the 1,000 to 1,500 most interesting sites seen by previous spacecraft. Furthermore, the “ground truth” (as Hubbard calls it) provided by

Then, in 2011, the first of several sample return missions will be launched, with its technology, design, and landing target determined by what has been learned during the previous decade of exploration.

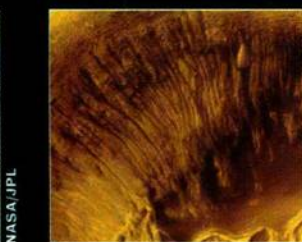
MARS ALIVE ... WITH HUMANS

Previous investigators too often allowed their preconceived notions about Mars to shape their research and conclusions. Mariners 4, 6, and 7 — instead of covering as wide an area of the planet as possible — were all aimed at the same southern dark regions where vegetation was supposed to grow. The Viking landing program was bent on a search for Earth-based organic life, rather than making a wider study of the martian environment.

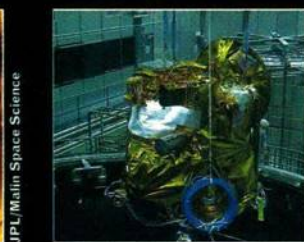
To prevent a repeat of these close-minded, narrow approaches, Hubbard radically changed the management style at NASA, insisting on trust, communications, and a clear chain of command. “You hear everybody out,” says



1999



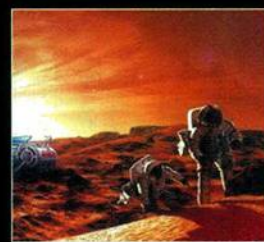
2001



2001



2005?



?

Left to right: NASA lost communications with the Mars Polar Lander as it arrived at the planet; MGS images just a few of many martian gullies that some scientists believe were once gouged by liquid water; Mars Odyssey Orbiter spacecraft enters a thermal vacuum chamber before launch; The 2005 Mars Reconnaissance Orbiter is depicted here soaring above the martian surface; Humans on Mars.

the 2003 rovers will allow scientists to better understand the orbiter’s spectral data.

In 2007, landers will be employed again and will use Reconnaissance Orbiter’s data to choose even more provocative landing sites. In addition, since the 2007 lander will be — in the words of Ed Weiler — “programmed for fear,” it will be able to distinguish boulders and unsafe landing sites in order to adjust its final descent accordingly. Thus its landing possibilities will be virtually unlimited.

Once on the ground, the rover — about five times bigger than the 2003 rovers — will have a range of more than 60 miles, and a lifespan of at least six months. “That landing will be an epiphany,” enthuses Garvin. “I guarantee that we will go to a place that will look like nothing we’ve ever seen.”

In 2007, NASA also plans to launch its first Scout mission. Intended as one of a series of very low-cost missions, approximately \$10 million each, the first Scout could be anything the scientific community wants it to be, from an unusual orbiter to a swarm of small landing probes.

That same year will also see the launch by NASA of an Italian Mars communications satellite, making possible the download of the gigantic amounts of data being gathered by the growing network of martian probes.

The 2009 missions, not yet determined, depend on negotiations with several international partners as well as the knowledge gained from the three previous probes.

Hubbard. “You don’t squash anybody that has a contrary point of view.”

Garvin meanwhile changed the goals of the program’s science portion, shifting it from the narrow focus of simply bringing back a Mars sample to having a wider overall vision. “We were really, really arrogant,” Garvin says, “to think we were just going to go and take a few more pictures, bring back a few samples, and answer the enigmas of Mars.”

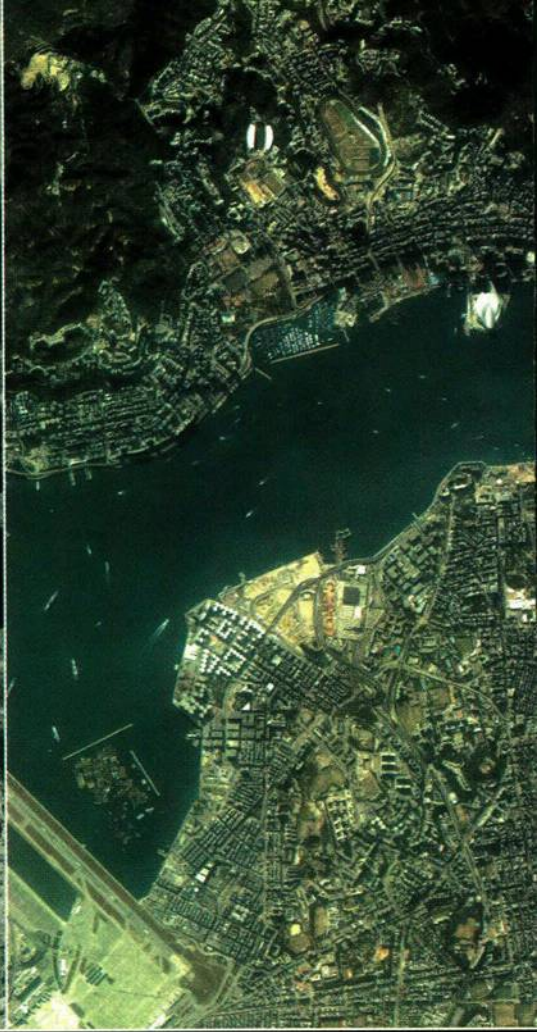
The result today is probably the first American space program whose goals are not focused around a single achievement, such as a lunar landing or a martian sample. Instead, the program is open-ended, recognizing for the first time that Mars is a big and complex planet, and that a full understanding of it will also be big and complex, requiring an extensive reconnaissance. “We’ve got to be prepared for good surprises,” Hubbard says. “Mars is just a weird place.”

In an open-ended program, each new mission is designed to ask new questions, which in turn will lead to new missions, which in turn will lead to new questions. Like a snowball rolling downhill, the exploration of Mars can only get larger and more exciting with time. From this momentum will naturally follow the first manned missions sometime in the early to mid 21st century.

Thus, this American caravan to Mars has a better chance of finding life than any previous single mission. And ironically, should it fail to find native martian life, the convoy will inevitably bring its own life to Mars — humans from Earth.

A

Robert Zimmerman is a frequent contributor to Astronomy. He lives outside of Washington D.C. and frequents NASA headquarters.



SEEING UNBLINKING EYE



THROUGH AN

The IKONOS satellite captures images of Earth from space as never seen before.

Text by Kelly Kizer Whitt

Naked-eye observers of the nighttime sky have long watched in amazement the illuminated reflection of satellites orbiting Earth. We gaze upward at these man-made mini-moons, some of which also gaze outward at stars and galaxies, some of which relay telephone and television signals across the globe, and some of which are gazing back at us. One of these is the IKONOS satellite, a commercial venture by Space Imaging that zips around Earth

IKONOS has the ability to capture photos of nearly anywhere on Earth, such as (left to right) the Hoover Dam, Hong Kong Harbor, and the pyramids on the Giza Plateau, near Cairo. All photos: Spaceimaging.com



Top: The River Thames is prominent in this photo of London. The Millennium Eye, a giant Ferris wheel, is visible overlooking the river. Bottom: The many tall buildings of Mecca cluster around the great mosque, which is the center for the Muslim religion.

at 4 miles (7 km) a second, 400 miles (680 km) above the surface. The remarkable power of IKONOS, however, is that it can resolve objects on Earth down to one meter in size.

IKONOS, which comes from the Greek word for "image," is in operation thanks to the cooperation of several institutions — Lockheed Martin built the satellite system, Eastman Kodak was responsible for the camera, and Raytheon created the communications and processing parts. Taking a page from old NASA operating procedures, two satellites were built in case one was destroyed during launch. And this is just what happened to the first satellite on April 27, 1999. A malfunction above the Vandenberg Air Force Base in California caused the initial IKONOS to burn up, with fragments plummeting into the South Pacific Ocean. The back-up IKONOS, which was successfully launched in September 1999, is fulfilling the hopes of those at Space Imaging, bringing incredibly detailed and accurate images to its consumers, whether they be government, industry, or simply private citizens.

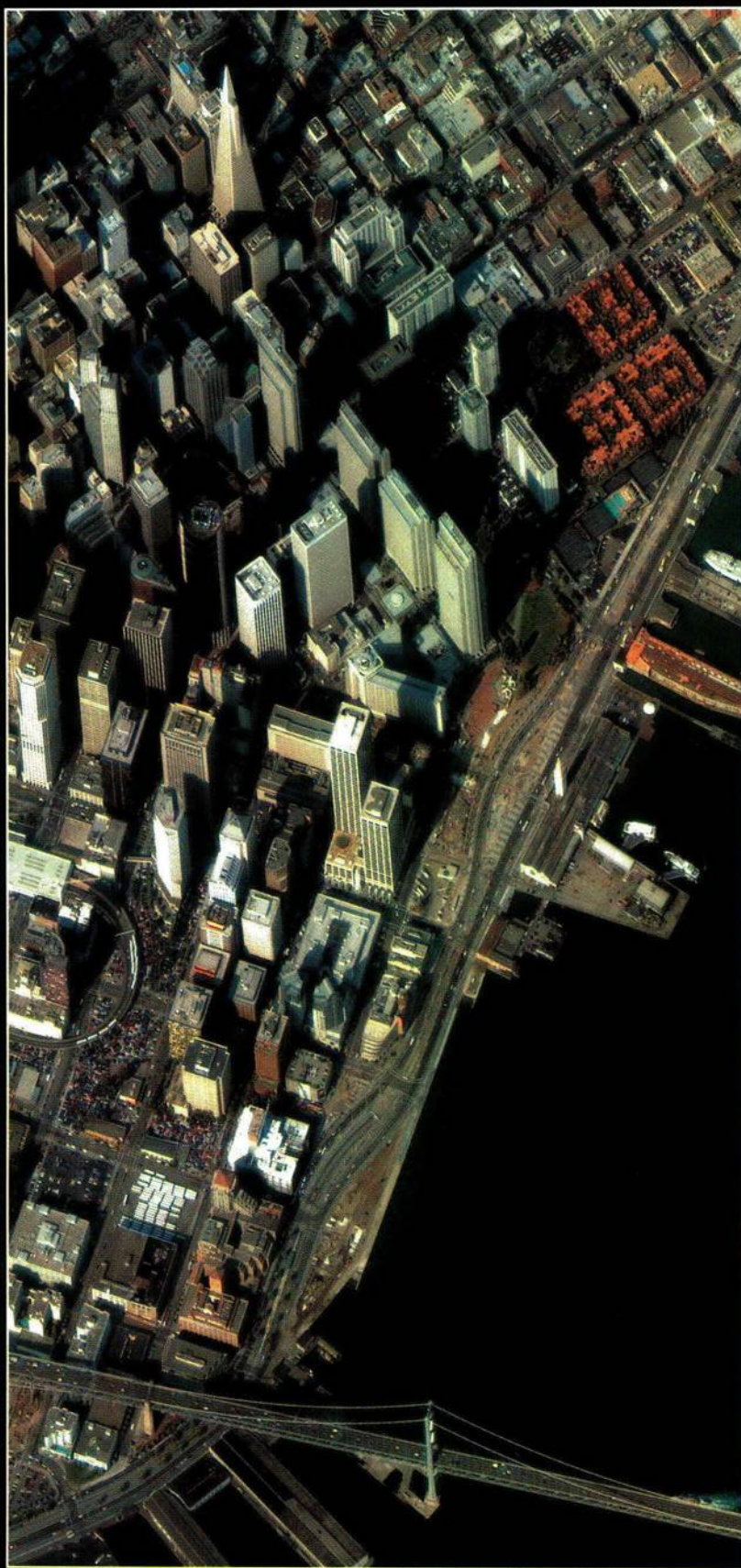
Designed to last five to seven years, IKONOS passes over any region of the globe about twice a day, and with favorable cloud cover the company claims it can produce a customer's request in as little as a few hours to within three days. Any area of the world is game to the eagle eye of IKONOS, with the exception of Israel, which cannot be imaged at less than two meters due to the Kyl-Bingaman Amendment to the Defense Appropriations Act. (This law was enacted in the late 1990s to protect Israel's security interests.)

Images that resolve down to one meter show remarkable detail, as seen on these pages. Vehicles, swimming pools, and gatherings of people are distinguishable, as well as areas with high color contrast, such as the stripes in a parking lot. The uses for such detailed pictures are endless. In agriculture, the images help to identify areas that are being ravaged by insects or drought. The high-in-the-sky view aids governments with city planning and tax assessment, while environmentalists now have a new tool for monitoring oil spills, pollution, population growth, and water shortages. The creators of IKONOS see no end to the uses of their unique 20/20 vision from space.

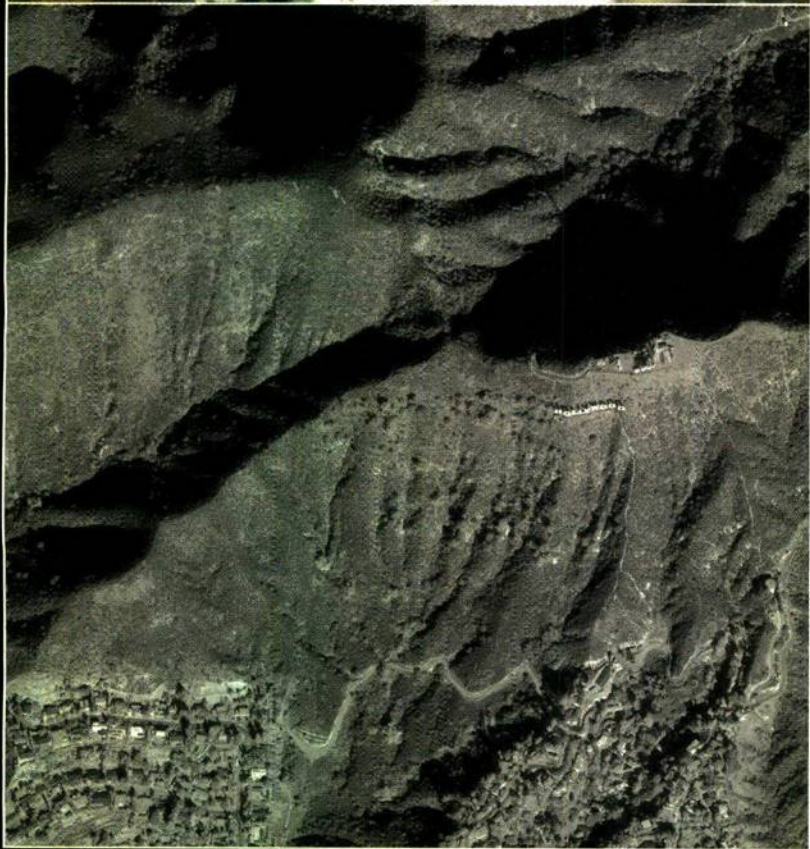
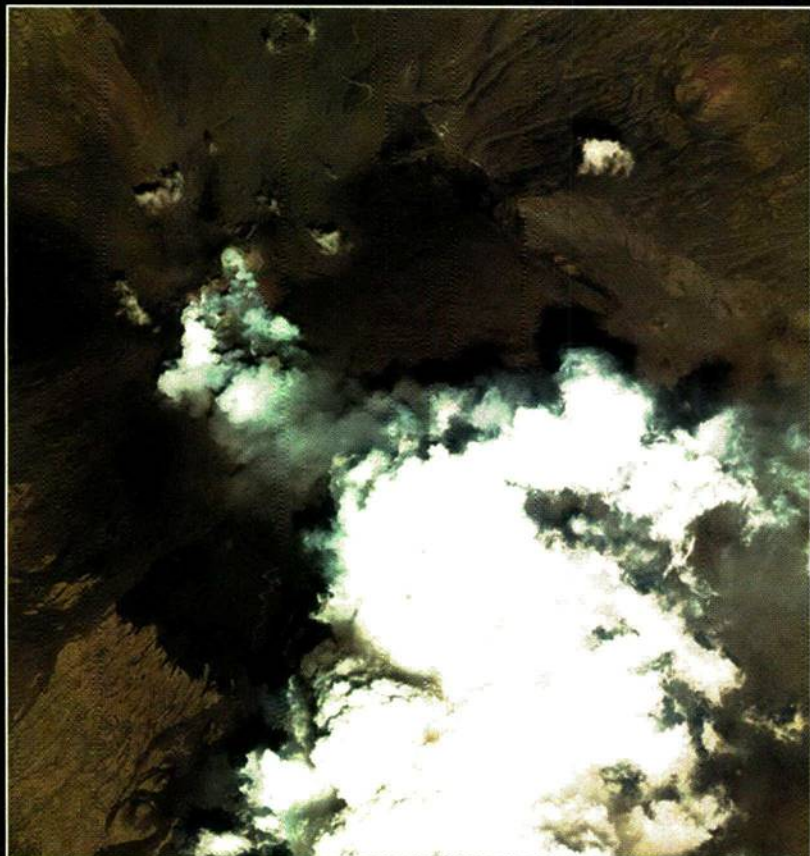
The selection shown here includes some well-known sites captured from IKONOS's unique perspective. The landmark Transamerica Building looms out from the only four-meter color image in our sample. Taken on October 21, 1999, the landscape of downtown San Francisco clearly reveals cars, trucks, road stripes, and trees. A couple hundred miles south of the City by the Bay, we find the Hollywood Hills, easily recognizable by the distinctive hilltop sign that was once part of a real estate advertisement. Many of the mansions dotting the hills belong to stars of movies, television, and music. Heading east, the last image from the United States included on these pages is of the mighty Hoover Dam in Nevada. This 726-foot-high feat of engineering was completed in 1935 with the purpose of holding back Lake Mead. The dam generates hydroelectric power, as evidenced by the large power grids visible near the bottom center of the picture.

Along the banks of the River Thames in London looms the Millennium Eye, erected to celebrate the dawn of the year 2000, with the Millennium Dome standing downstream. Queen Elizabeth II and her subjects celebrated the millennium at this spot at midnight on December 31, 1999, with a grand fireworks display. On the other side of the world stands another construction project finished in the past couple years for a recent major event: the Olympic Park of the 2000 games in Sydney, Australia. Visible are the Main Stadium, Superdome, Athletics Center and warm-up arena, Aquatic Center, and the hockey, tennis, and baseball venues. Each of these sites required extensive security measures, which these photographs could aid in the development of in the future. Likewise, the image of bustling Hong Kong Harbor includes the Bank of China and the Hong Kong Convention and Exhibition Center, along with other locations that could benefit by high-in-the-sky visuals for security or even city-planning strategies. Most noticeable in this amazing photo of Hong Kong are the white wakes streaming behind the many boats in the harbor.

From overhead, the Egyptian pyramids at Giza are instantly familiar. The size of the base of the Great Pyramid of Khufu can be compared with the many houses lining the left side of the photograph. Can you spot the Sphinx



The Transamerica Building looms in this remarkable image of San Francisco. The San Francisco-Oakland Bay Bridge stretches across the bottom of the image.



Top: Mount Etna, located in Sicily, erupts powerfully on July 31, 2001. Bottom: The famous Hollywood sign is visible in the cliffs toward the upper right of this unique photograph of the Hollywood Hills.

in the image? Not too far east is Saudi Arabia, where IKONOS acquired the image of Mecca. The great mosque, al-Haram, is where all Muslims must make a holy pilgrimage to in their lifetime, called a hajj. A group of people can be seen at the center of the enclosed area; non-Muslims are not allowed inside the walls. Minarets, towers from which the people are called to worship, dot the landscape of the city.

Newsworthy events that the commercial satellite has covered include March 2000 images of the Fort Worth,

EYE ON *SURVIVOR*



IKONOS's eyesight appears to have no limit. In fact, the satellite had the honor of taking the first high-resolution images of the secret CBS *Survivor: Africa* camps, located in the Shaba National Reserve in central Kenya.

According to the website "Survivor Maps," satellite images, collected on August 13, 2001, show what viewers never see at home — the large CBS production camp that is required to produce the show. The image above shows the production compound including mess hall, temporary production buildings, motor pool and sleeping tents. Another image (see page 6) highlights one of the contestant tribal camps, a tribal Maasai-style village of 10 thatched huts with a circular thornbush fence. While *Survivor* tribes may appear to be isolated, the two camps are only two miles apart.

"It was a real pleasure to deal with such an untraditional customer," said Space Imaging's Mark Brender.

Dan Bollinger, creator of "Survivor Maps", determined the location of *Survivor: Africa*. "Because the government of Kenya has designated a no-fly zone over the park, the only way I could truly show the size of the CBS operation was to have an image taken from space," said Bollinger. "What I discovered is IKONOS is an eye-in-the-sky available to anyone."

— *Elesa Janke*

Texas, area after it was hit by a tornado. It has also photographed the earthquakes in Turkey and the flooding and mudslides in Venezuela and Mozambique. And in April 2001, IKONOS imaged the U.S. Navy spy plane that was being held at a Chinese air base.

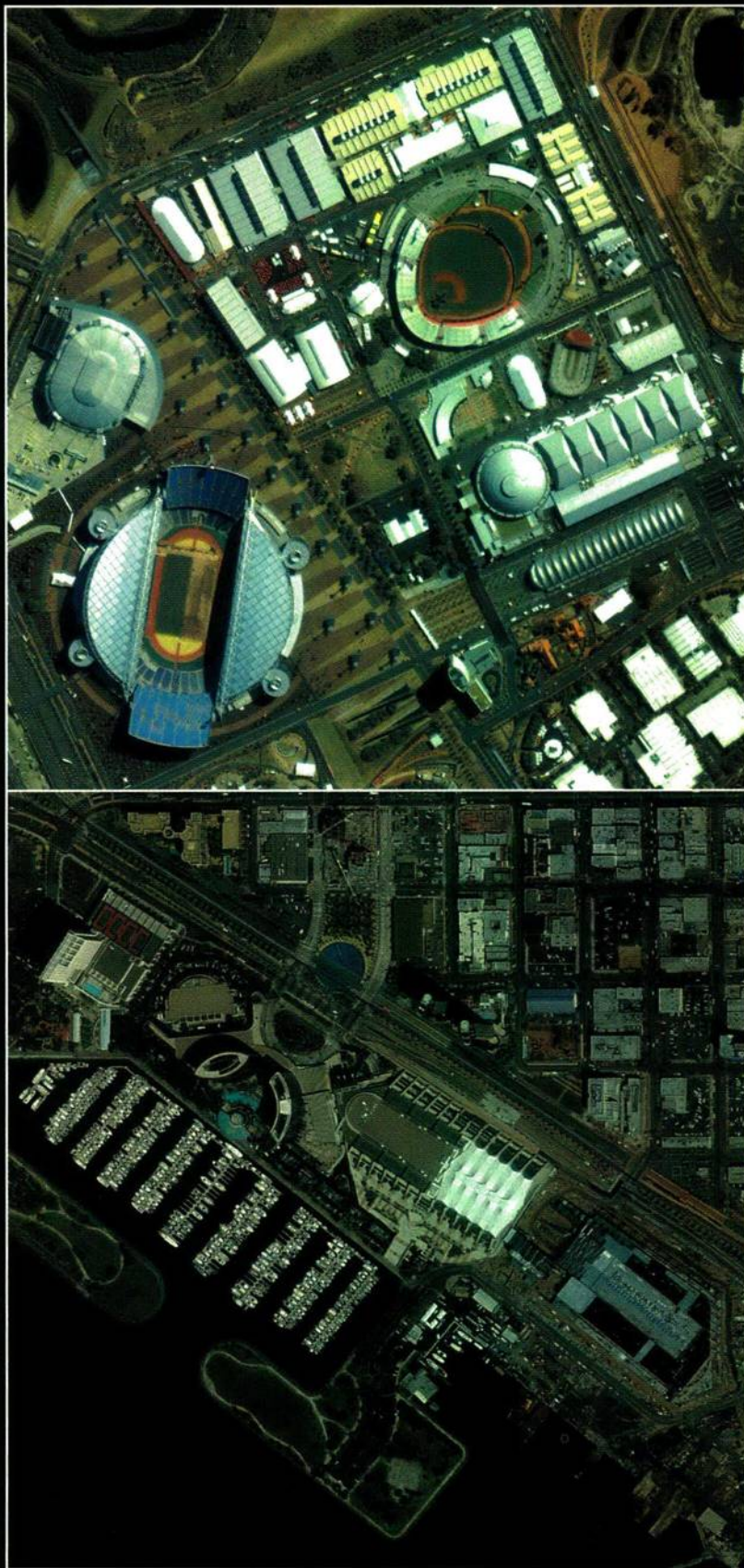
IKONOS has captured many other disaster images as well. Such photos can be very beneficial in damage assessment and emergency management. Shown at left is a photograph of the eruption of Mount Etna in Sicily, taken on July 31, 2001. The volcano had been spewing molten lava, rock, and ash from its southern slope for two weeks prior to this photograph, causing the surrounding area to be declared a state of emergency.

Many more disturbing photos, which are not printed here but are available for viewing online, have also been taken since the launch of IKONOS. In December 1999, the satellite photographed the city of Grozny in Chechnya, showing downtown Grozny and the Sunzha River that cuts across it. In another image, taken on March 16, 2000, some of the structures around the square are completely obliterated, and craters from bomb blasts scar the city. Although taken at different times of day, the images show changes such as shadows cast by buildings that were subsequently destroyed.

But by far the most disturbing images were captured over New York City and Washington, D.C., following the acts of terrorism that devastated these cities on September 11, 2001. From its vantage point in space, IKONOS collected images of the spot where the World Trade Center towers once stood, the buildings replaced by piles of rubble and clouds of smoke. The satellite also photographed the Pentagon, showing an entire section of the building reduced to ash and rubble. Photos of both landmarks, before and after these tragic events, are also viewable online.

If you are interested in obtaining your own IKONOS images, Space Imaging offers them online for \$10 a picture. One meter black-and-white and four meter color images can be downloaded instantly. For more information and to view images, go to spaceimaging.com. **A**

Kelly Kizer Whitt, former copy editor of Astronomy, is a freelance writer and editor.



Top: This image of Sydney, Australia, showcases the home of the 2000 Olympic games. **Bottom:** Visible in this shot of San Diego is the trolley line and Embarcadero Marina and Park.



FROM HERE

On the search for meaning in an accele

Some years ago a memorable commencement exercise took place at a well-known private girls' school. The speaker is reported to have proceeded to the podium, all the while surveying the smiling girls in their bright white graduation gowns, surrounded by their parents and friends. Looking out at the crowd, he began, in a booming voice: "Things are going to get unimaginably worse, and they are never, ever going to get better again!"

I heard this story as a student, and do not know whether it is apocryphal. Nevertheless, I have always wanted to recount it in writing, and this seems like the perfect place. As the universe evolves there will continue to be, at least metaphorically, moments in the sun, perhaps for all eternity. But these will be fewer and farther between. If we peer as far as we can into the future of life, the universe, and everything, things do not look good.

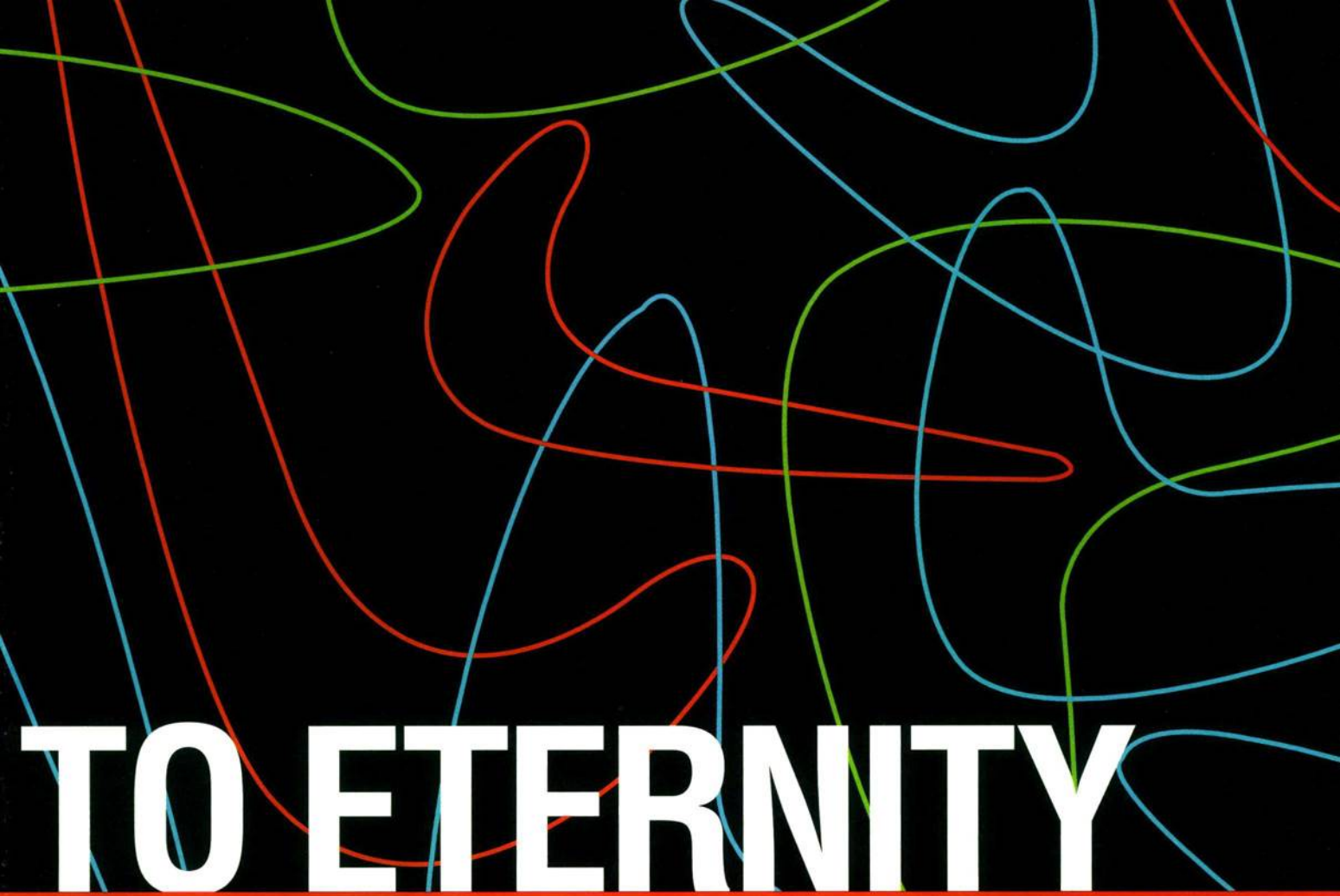
GRAVITY SUCKS

Discoveries made over the past five years suggest that we actually may live in the worst of all possible universes, at least in terms of the long-term quality and perdurability of life. And the same theoretical developments that hold out such hope for understanding why we live in a universe full of matter also imply that ultimately, this matter is ephemeral.

Before 1916 it made no real physical sense to discuss the future of the whole universe, because no theory existed that could consistently describe the dynamics of space, time, and matter. In that year, however, Albert Einstein completed his greatest piece of work, the discovery that would make him a household name and the Man of the Century. Against all intuition, the space in which we live is actually curved, and it is the matter and energy content of the universe that is responsible for this curvature. Einstein's General Theory of Relativity yielded the necessary links between space, time, and matter. As such, he quickly realized, it offered the possibility of not merely describing the motion of objects within the universe, but the behavior of the universe itself.

There was a problem, however. Einstein's universe shared with Newton's a fundamental problem: Gravity sucks! That is to say, gravity appears to be universally attractive, unlike, say electric or magnetic forces, which can be attractive or repulsive. As a result, there exists no stable static configuration of matter spread out throughout the universe. The gravitational attraction of massive objects will invariably cause them to collapse together.

Einstein's problem was that in 1916, conventional wisdom held that the universe was static. After all, if we look up into the heavens, do not the distant stars appear immovable? Einstein was disheartened by this realization, but not daunted. He



TO ETERNITY

rating universe. by Lawrence M. Krauss

recognized that he could make a minor alteration in the equations governing the evolution of the universe that would solve this problem. He added an extra term, which he called the cosmological term, which would produce a very small repulsive force throughout all of space. On human scales, and the scale of our solar system, this small additional force would be unnoticeable. On the grand scale of the universe, however, this force could balance the gravitational attraction of distant galaxies, and keep them apart. Almost immediately, however, this idea ran into problems — so many, in fact, that Einstein quickly labeled it his “Biggest Blunder.” We should all be so lucky.

EINSTEIN'S STATIC FLING

First of all, within a decade or so of Einstein's “blunder,” it had become clearly established that the universe was not, in fact, static. By 1929, the American lawyer-turned-astronomer Edwin Hubble had published his study of an expanding universe. But even earlier, the notion that the universe might not be static was in the air. In 1923, Einstein wrote in a letter to the mathematician Hermann Weyl: “If there is no quasi-static world, then away with the cosmological term!”

You see, if the universe is expanding, there is no need for a universal repulsive force in nature. Gravity can simply work to slow the expansion. Depending on how fast the expansion is, and how much matter there is to slow it, the

universe will either go on expanding forever or it will slow down, stop, and collapse. Trying to determine which future is ours then became one of the central industries of cosmological research.

Much as Einstein wanted to get rid of the now unnecessary extra term in his equations, this was a little like trying to get the toothpaste back in the tube. Had Einstein not introduced this term, someone else would have.

THE ENERGY OF NOTHING

The cosmological term turns out to have a real physical significance, or at least a significance that may be real. In general relativity, energy, in any form, is the source of gravity and hence of the curvature of space. And it turns out that one very particular type of energy produces precisely the effect of Einstein's cosmological term. This is the energy of nothing at all.

Now, you may say that in any sensible world “nothingness” cannot be possessed of energy. But no one has ever claimed that quantum mechanics is sensible. In fact, quantum mechanics, when coupled with Einstein's Special Relativity

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Theory, implies that empty space is not really empty. It is full of a seething bubbling brew of elementary particles, called virtual particles, that can suddenly appear, and can disappear back into nothing in a time so short that you cannot observe them directly.

This may sound suspiciously like describing how many angels can dance on the head of a pin, but there is an important difference. Angels are invisible, and normally unmeasurable. Virtual particles are invisible, but they measurably affect almost every microscopic process in the universe. On such scales, for example, virtual particles can change the properties of atoms, by momentarily altering the distribution of electric charge. This in turn will affect the energy levels of electrons orbiting the atoms in ways that can be calculated, and the predicted change agrees with the measured change more accurately than any other prediction in all of physics.

If empty space is truly full of virtual particles, then the question arises whether these particles can also contribute energy to space. If they can, then the cosmological constant will not be zero. Unfortunately, when we try and estimate how much energy such quantum effects can contribute, the typical prediction is about 120 orders of magnitude larger than all of the energy contained in all of the stars, gas, planets, and people in the entire visible universe.

There is a simple experiment anyone can do to demonstrate that empty space cannot contain such a mammoth store of energy: Look at your own nose. Indeed, as the novelist George Orwell once wrote: "To see what is in front of one's own nose requires a constant struggle." This takes on a whole new meaning in a universe with a cosmological constant. In such a universe, the repulsive force in empty space causes distant objects to move apart with a relative velocity proportional to the distance separating them. This means that objects separated by greater than a certain distance will actually be moving apart faster than the speed of light!

This may sound impossible, but while special relativity precludes objects traveling through space faster than the speed of light, general relativity implies that space — whose expansion can carry the objects apart — has no such restrictions. The effect of objects separating faster than the speed of light is that one object becomes invisible to the other, since the light from one cannot compete with the expansion of space in order to traverse the distance between them.

As a result, we can put a limit on the magnitude of a cosmological constant. If it were larger than a certain value, the space between your eyes and your nose would be expanding faster than the speed of light. The light from the end of your nose would thus never reach your eyes. For this not to occur, the maximum allowed cosmological constant is at least 70 orders of magnitude smaller than the naïve prediction resulting from the estimate of the energy of empty space I alluded to above.

But we can do far better than this. We can see not only the ends of our noses, but, with our telescopes, we can see

throughout the universe. The fact that we can see distant galaxies billions of light-years away from us puts by far the strongest available constraint on the magnitude of a cosmological constant, about 120 orders of magnitude smaller than the naïve estimate above.

Nevertheless, as small as this value is, it allows for an absurdly small cosmological constant to exist. It is even possible that the energy density of space could still exceed that associated with all matter in the universe.

As absurd as this may sound, about five years ago, Michael Turner of the University of Chicago and I, along with several other independent groups, proposed that this was the case in our universe. We recognized that the available data from cosmology, pertaining to the age of the universe, its composition, and the distribution of matter, when combined with theoretical arguments, yielded a highly suggestive, and highly heretical possibility: At least 60 percent of the energy of the observable universe seemed to reside in empty space.

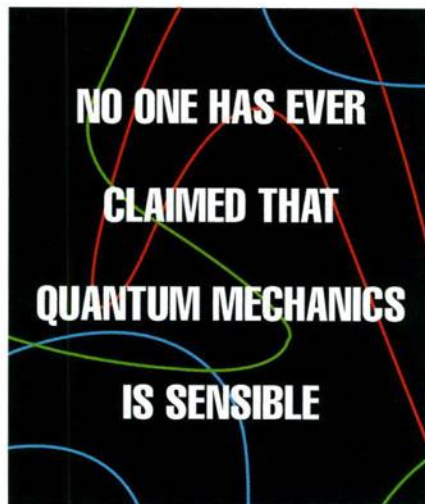
If this were true, it would imply that the present expansion of the universe should be accelerating, rather than slowing down, as would be the case in all conventional theories in which the universe was dominated by matter or radiation. As if on cue, within two years, two different international collaborations, one led by Brian Schmidt at Mount Stromlo Observatory in Australia and Robert Kirshner at Harvard University, the other by Saul Perlmutter at Lawrence Berkeley National Laboratory, reported the results of a bold new effort to measure the acceleration or deceleration of the universe, using a special kind of exploding star called a Type Ia supernova — a cosmic thermonuclear bomb of sorts — as their guide.

THE BEST OF TIMES

In January 1998 the groups independently announced a discovery that rocked the scientific community, and was even labeled the "Discovery of the Year" by *Science* magazine. Their data implied that the expansion of the universe is accelerating. What's more, the estimate of the required energy in empty space agrees precisely with that which we earlier inferred on the basis of indirect arguments. Now, in spite of this remarkable consensus, the supernova data remain preliminary, and it is premature to suppose that they will not later be proven wrong. But if they are confirmed, empty space would possess more energy, on average, than anything else in the universe.

If these observations survive the test of time, the implications for our understanding of fundamental physics are indeed profound. But the implications for the possible future of the universe are even more dramatic.

If the expansion of the universe is accelerating, we can ask how long it will take before most of it has disappeared from our view altogether. The answer my colleague Glenn Starkman and I recently derived is surprisingly soon, at least in a cosmic sense. Within about two trillion years not a single object outside our local supercluster will be detectable by any means whatsoever. We will become truly alone in the universe, forever and ever.



Of course, there is a bright side to every dark cloud. I have used this argument, for example, to emphasize to those in government who fund cosmology that if the expansion of the universe is accelerating, we have only a limited time to make our observations, and they had thus better give us the money now. More relevant to the matter at hand, once we acknowledge the possibility that empty space can have energy, our ability to unambiguously predict the future of the universe goes out the window. Geometry is no longer destiny.

Without a cosmological constant, it was safe to claim that if there is sufficient mass around, this would ultimately slow the expansion of the universe, causing it to stop and reverse. If the mass density were not sufficient, the universe could expand forever. If vacuum energy dominates, however, then no matter how big the mass density, or how it might alter the geometry of the universe, it cannot be sufficient to stop an already-accelerating universe. Alternatively, even if the mass density is too small for its cumulative gravitational attraction to slow the expanding universe, a negative energy in empty space could still result in an extra attractive force throughout space. This would eventually stop the current expansion.

Michael Turner and I have argued, in fact, that no finite set of measurements one can make over any finite amount of time will allow us to know unambiguously the fate of the universe. As long as physics remains an empirical science, guided by experiment and observation, the ultimate future of the universe will remain an ultimate mystery.

THE SPEED OF LIFE

Must we then end this tale in such a state of ambiguity? Is there nothing at all we can say about either the fate of life, or the ultimate future of our atoms in such an uncertain universe?

Humans are innately optimistic about the future, perhaps because without that optimism, much of the hard work of living may seem pointless. We believe our progeny will survive. Death and taxes, pain and suffering might never disappear, but somewhere our children will carry on. If necessary, we will colonize the galaxy just as life has thus far colonized every possible niche on Earth. Or so we hope.

Charles Darwin was just such an optimist. In the conclusion to *On the Origin of Species*, he wrote: "As all the living forms of life are the lineal descendants of those which lived before the Cambrian epoch, we may feel certain that the ordinary succession by generation has never once been broken . . . Hence we may look with some confidence to a secure future of great length."

Darwin undoubtedly thought life could survive the cataclysms that will inevitably follow in Earth's future. But what about the eternity of time that may exist beyond the demise of Earth? In Darwin's day, before the expansion of the universe was known, scientists worried that eventually life was doomed to what is known as "heat death." Eventually, a static universe would reach thermal equilibrium, in which the whole cosmos would come to a common temperature. If there are no energy sources or sinks, the famous second law of thermodynamics implies that in such a universe, useful work will no longer be possible.

But life demands a localized departure from global equilibrium. Life is a thief of energy, hoarding it for later use. Eventually life spends its energy balance in the process of

living, and as required by the laws of thermodynamics it releases energy as heat in the process. Heat energy can be used for work only by transferring heat from a hotter object to a colder one. Once all there is in the universe is heat energy at a uniform temperature, there will be nothing left to steal.

The discovery in the 1920s that the universe is expanding changed everything, however. In an expanding universe, the background temperature generally decreases continually, delaying the onset of such heat death. A continually expanding universe that cools forever thus appears to offer new hope for life.

There is a long road from hope to accomplishment, however. In practice one must always confront this Universal Fact of Life: Batteries are required. Life will always depend on inventing new ways to steal energy from a changing environment in order to power the processes of reproduction and metabolism.

When life first arose on Earth this larceny was probably accomplished by accident. With abundant energy there was more than enough opportunity for complex molecules to arise. But just as we will one day in the not-too-distant future have to face the fact that the fossil fuel energy reserves on Earth are limited, as time marches on all local energy reserves will also dwindle. The march of time is a march toward equilibrium, but if life is to continue, it must stave off the arrival as long as possible.

NOTHING LEFT TO LIVE FOR

On Earth, we know precisely how much energy is required to power life, and if we continue at our current rate of energy consumption, it is the work of a moment to estimate how much time we have left. But estimates based on our current metabolism do not necessarily provide an accurate guide for the future. If intelligence survives the solar system catastrophe and moves out to populate other parts of the galaxy, and if it survives the collision of galaxies and the dying of stars, it will do so by subsisting on ever less and less energy over time. There is only one way to reduce its energy needs. Like many a civilization in those early *Star Trek* episodes, it must ultimately shed its cumbersome body, seeking out means of preserving itself at a lower energy cost.

As the stars dim, and the universe cools, civilizations will face the ultimate limits to their existence. Whether or not they can survive the challenge, even in principle, is not yet resolved. In a landmark paper published in 1979, the brilliant British-born mathematical physicist Freeman Dyson, of the Institute for Advanced Study in Princeton, laid the groundwork for the challenge facing civilization in the ultimate future.

It may seem that in a possibly infinite universe that may expand forever, there should be infinite energy reserves to draw on. This is probably not the case, however. As the universe expands, the density of matter, and available energy, decreases. Life would be required to mine a larger and larger volume to extract smaller and smaller amounts of energy. Indeed, my colleague Glenn Starkman and I have claimed that there is no mechanism to extract an ever increasing amount of energy out of an expanding universe, even in an infinite amount of time. If we are correct, then life must ultimately face a budget problem unlike any that it has faced thus far: how to make a finite energy reserve last an indefinitely long amount of time.

LIVING FOREVER

In his earlier work, Dyson addressed this very question. In a manner typical of his great ingenuity, Dyson, who freely admits an eternal optimism, demonstrated that contrary to one's naïve expectations, eternal life with finite energy is not in principle impossible. He made two simple assumptions, which may not be realizable in practice but which are certainly at the very least plausible. First, assume that life can continue to modify its bodily housing so that its metabolism uses less and less energy with time. Second, assume that for a civilization of conscious beings eternal existence is equivalent to continuing to have conscious thoughts, so that an infinite number of conscious awakenings is equivalent to eternal life, if not for a single being, then for a civilization of beings.

One can argue with either of these assumptions, but one must agree that this is a "minimalist" interpretation of conscious life. If life cannot achieve even this level of existence, then surely anything more is impossible.

In this regard the physics of infinity is no less tricky than the mathematics of infinity. Dyson pointed out that an infinite conscious future is possible even if living systems remain unconscious for an ever-increasing amount of time. Like bears in the winter, life can hibernate. Even if the periods of hibernation get longer and longer, in a universe that persists forever there is an infinite amount of time to spare. This may sound like an absurdly baroque argument, but Dyson proved that in a universe with limited energy resources, there is no other possibility for life, even in principle.

Starkman and I have recently argued that even this possibility is overly optimistic. We have claimed that even in an eternally expanding universe, life cannot persist forever. We base our claim on the assumption that ultimately, as energy reserves decrease, the laws of quantum mechanics will govern the future of life. One of the reasons that the quantum world seems so strange to us is that with every breath we take, we deal in huge numbers of particles. We have seen how this fact can lead to remarkable connections between all living things. However, it masks the fact that we now understand that at a microscopic level, energy is transferred between objects in discrete amounts, first called quanta by the German physicist Max Planck. Once one begins to investigate the universe at a level where individual quanta become significant, its weirdness becomes manifest.

If one takes the discreteness of nature at a fundamental scale into account, then the mathematics of living is different than it would be if one could continue to treat energy as a continuously variable quantity. We have argued that once the energy required to power a living system becomes small enough, then the discreteness of energy transfers will become important, and in this case life, at least life that continues to think new thoughts, cannot endure forever.

Dyson has likened the difference between our form of "quantum life" and his continuous version of "classical life" as the difference between whether life is ultimately "digital"

or "analog." In the former case, like a programmable computer, intelligent computations can be discretized into a series of "bits," ones and zeroes. One may use such ones and zeros to play chess, or even encode and play back complicated music. Analog systems on the other hand, do not rely on such discreteness. Old-fashioned record players, for example, reproduced music by continually varying the pressure on a mechanical needle, which in turn converted these mechanical impulses into a continually varying electrical signal.

Dyson has accepted our conclusions about the ultimate limits to quantum living, but he has held out the possibility that life might ultimately avoid this quantum catastrophe if it plays its cards right. The future, one might claim, thus lies

not in CDs, but in LPs. As an example, he has resurrected a famous bit of science fiction lore, due to the astrophysicist-science writer Fred Hoyle, a classic tale about a "Black Cloud," in which a diffuse cloud of particles roamed the universe, and all the while was actually a conscious life-form. Its thoughts and actions were encoded in the motion of the particles making up the cloud.

Such a black cloud, Dyson has argued, is an example of an ultimate classical life-form, one that, as it slowly expands, can have a metabolism that continues to utilize less and less energy without approaching the quantum limit, and one that can, in principle, sleep for extended periods.

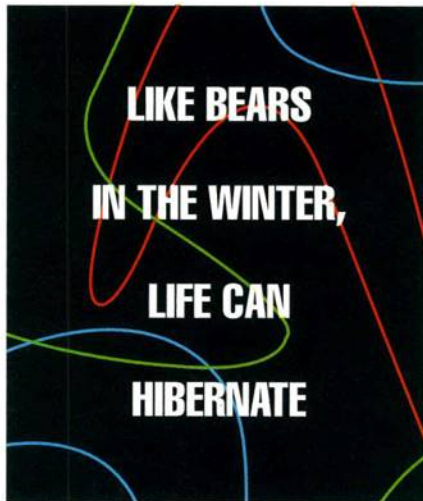
REWARDS IN HEAVEN?

This issue is not yet settled. Dyson, Starkman and I continue our friendly debate about a subject that is perhaps of only academic interest at present. The energy resources in our galaxy may be finite, but they are immense.

Even at our present rates of energy usage, life could go on living for an unfathomably long period, literally billions, and billions, and billions, and billions of times longer than the present age of the universe. Yet I nevertheless find it seductive to imagine that arguments based on simple laws of physics might allow us, rudimentary beings that exist in the earliest energetic heyday of our universe, to peer into our looking glass and divine the remote future of civilization.

There may be no ultimate purpose to our existence, or the existence of our atoms. The universe may become unimaginably worse, or it may not. There may be no reward in heaven. But surely the possibility that we, as conscious beings, have some hope of unraveling the secrets of a mysterious universe in the time we have allotted is itself a precious gift we should not squander. ■

Lawrence M. Krauss is the Ambrose Swasey Professor of Physics, Professor of Astronomy, and Chair of the Department of Physics at Case Western Reserve University in Cleveland, Ohio. He is the author of several popular science books, including The Physics of Star Trek (HarperCollins, 1996).



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SkyMap Pro 7.0 95

Solar filt- 60/70 68

Solar filt-dlx-90 82

Solar filt-dlx-125 104

Telescope extender 32

Visual back 1.25" 32

Wide-field/deluxe 100

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Autostar #497 100

Ac adapter #541 42

Ac adapter #546 22

Car cord #607 30

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Case #765 40

Case #773 (60/70) 62

Case #774 (90) 100

Case #775 (125) 150

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Nebula 908 O-III 100

Nebula 911 B 100

Nebula 911 N 120

Nebula 911 O-III 150

Off-axis standard 87

Off-axis deluxe 114

Pictor 201XT 399

Pictor 208XT 499

Pictor 216XT 699

Pictor 416XTE 1999

Pictor 616 filter 699

Piggy brkt 7/8" 34

Piggy brkt 10" 34

Piggy brkt 12" 50

Prism 2" 90° 105

Prism 1.25" 90° 45

Prism 96-1.25" 32

Prism 1.25" 45° 45

Skylight/seal 50

Tele ext-variable 40

T-adapter: SCT 30

T-adapter: var-proj 40

T-adapter: 12" 30

Var pol 905 50

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10" full aperture 159

12" full aperture 189

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9" heater 52

9/10" heater 62

12" heater 72

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7/8" 54

10" 64

12" 85

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LISTENING FOR E.T.

Radio astronomer Kent Cullers teaches SETI computers to look for deep-space signals from extraterrestials.

Text by Sally Stephens
Photos courtesy Seth Shoshak/SETI Institute

As a young boy, Kent Cullers stayed up all hours of the night fiddling with the dials on his shortwave radio, searching for far-away transmissions as the ionosphere rose. “I used to look for signals from Africa,” he says. “Now I look for signals from ‘E.T.’”

Cullers, Director of SETI Research and Development at the SETI (Search for Extraterrestrial Intelligence) Institute in Mountain View, California, has been searching for radio signals from intelligent aliens for more than 20 years. He writes the algorithms that allow astronomers’ computers to sift through billions of radio channels, searching for signals that can only come from technologically advanced civilizations.

“I’m in one of the few fields where being blind is a help,” says Cullers. “It causes me to concentrate on what I hear.” David Kent Cullers — he



Above: Kent Cullers near a satellite dish outside SETI headquarters in Mountain View, California. **Facing page:** Arecibo, Puerto Rico, is the site of the world’s largest spherical reflector and SETI’s primary data source. Built over a karst sinkhole, the dish measures 1,000 feet (305 meters) in diameter spread over 20 acres.



prefers Kent — was born prematurely in El Reno, Oklahoma, in 1949. The pure oxygen pumped into the incubator that saved his life clouded the lenses of his eyes and destroyed his retinas.

"My parents always told me I could do anything," Cullers remembers fondly. Physically active, he climbed trees, played a form of baseball, and raced bicycles with neighborhood friends. "I was never good at listening to 'You can't do that,'" he says.

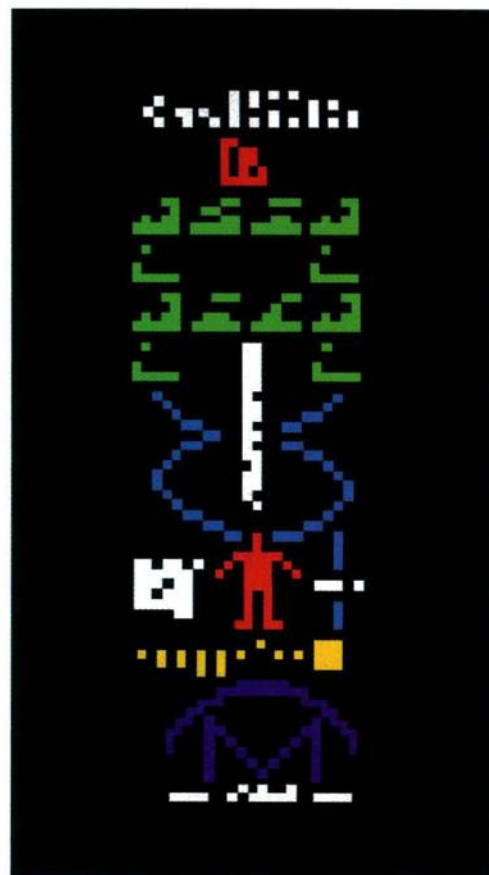
Indeed.

"Kent's work for SETI has been brilliant," says Frank Drake, Chairman of the Board of Trustees of the SETI Institute. In 1960, Drake conducted the first radio search for alien signals. Cullers's algorithms form the computational backbone of Project Phoenix, a privately funded SETI search.

With characteristic modesty, Cullers attributes much of his success to living at the right time, with the right technology. His computer is connected to a state-of-the-art Braille notetaker which converts text into Braille or speech so he can read e-mail and other text documents.

On the desk in his small, windowless office, pictures of Cullers's wife and two children stand alongside a small wooden statue of a dolphin he keeps to remind himself how hard it is to communicate with other life forms. A flat stone plaque rests elsewhere on his desk, with the words, "Nothing is Written in Stone" carved into it, while a talking clock calls out the hours.

"I'm in one of the few fields where being blind is a help. It causes me to concentrate on what I hear."



SETI Institute

On November 16, 1974, astronomers sent this binary encoded message toward globular cluster M13. It's an encoding of our chemical makeup, our planetary system, and other pertinent data.

All SETI, All the Time

By fall 2002, Kent Cullers will have even more ways to listen to the stars, thanks to the Allen Telescope Array (ATA). Funded by former Microsoft executives Paul G. Allen and Nathan P. Myhrvold, the ATA is designed specifically for SETI.

It consists of approximately 350 satellite dishes, each about 20 feet (six meters) in diameter, with a combined collecting area of 2.47 acres (one hectare). This design allows researchers to electronically combine the ATA's output in various ways. Added up one way, the telescope beam favors a radio wave coming from one direction; added a different way, the beam favors a wave coming from an opposite direction. "If you have the computing power," Cullers says, "you can add them up in multiple ways and form multiple beams."



This gives the array the flexibility of looking at a SETI target star while simultaneously observing another astronomical object — like a pulsar or interstellar gas cloud — elsewhere in the sky.

It all depends on how the outputs of the component dishes are combined. "We're developing a technology that's not just good for SETI," Cullers says, "but good for all of radio astronomy."

Seven 12-foot dishes collect radio waves in this Rapid Prototype Array, a testbed for the Allen Telescope Array.

While the ATA undergoes technical development, the SETI Institute plans to begin testing its prototype ATA by October 2002. This version will run for six months before the larger array becomes operational, according to Jill Tarter, director for SETI. — S. S.

Cullers's red-tipped white cane leans discretely in the corner.

Sometimes, to get into the right frame of mind, Cullers listens to the night sky. He says it mostly sounds like white noise — what you hear when you're not tuned to a radio station. But when he listens to a maser (a type of amplified microwave emission, analogous to a laser), he discerns different sounds, as if the noise changes its character. His trained ear picks up subtle, narrow frequency components over the noise in much the same way his computer algorithms find alien signals. In effect, his algorithms are a way of teaching computers to do the same thing the human ear does, but with much greater sensitivity. "The computer detects signals that are about a thousand times weaker than what the human ear detects," he says.

Making Contact

Cullers found his true calling — signal detection — in graduate school at the University of California at Berkeley. His 1980 doctoral thesis analyzed a layer of ionized gas, or plasma, in Earth's upper atmosphere by studying changes in the strength and frequency distribution of radar waves. Cullers developed computer algorithms to pull the weak backscattered radar signals out from the general cosmic noise.

While working on his thesis, he read about Project Cyclops — a plan to use radio telescopes to detect alien transmissions. The idea of communicating with other civilizations captivated his imagination. He realized that his algorithms were just what SETI researchers needed to find weak alien signals amidst a sea of background noise. The next step was convincing the SETI Institute that it could use his equations.

By chance at the wedding of a mutual friend, Cullers happened to sit across from Jill Tarter, director for SETI. Cullers was soon working with Tarter, writing algorithms that would scan the cosmic static and differentiate regularly spaced pulses from continuous signals that slowly "drifted" in frequency. "Phoenix and its unique capabilities really are very much the product of Kent's fertile imagination and brilliance," says Tarter.

Others are captivated by Cullers's determination, also. For instance, while working on NASA's SETI program, Cullers met George Miller, the original director of the movie *Contact* (1997), in which Jodie Foster plays a radio astronomer who detects an alien signal from a planet orbiting Vega. Miller was so impressed by Cullers that he added the character Kent Clark — a blind researcher — to the movie script.

Project Phoenix

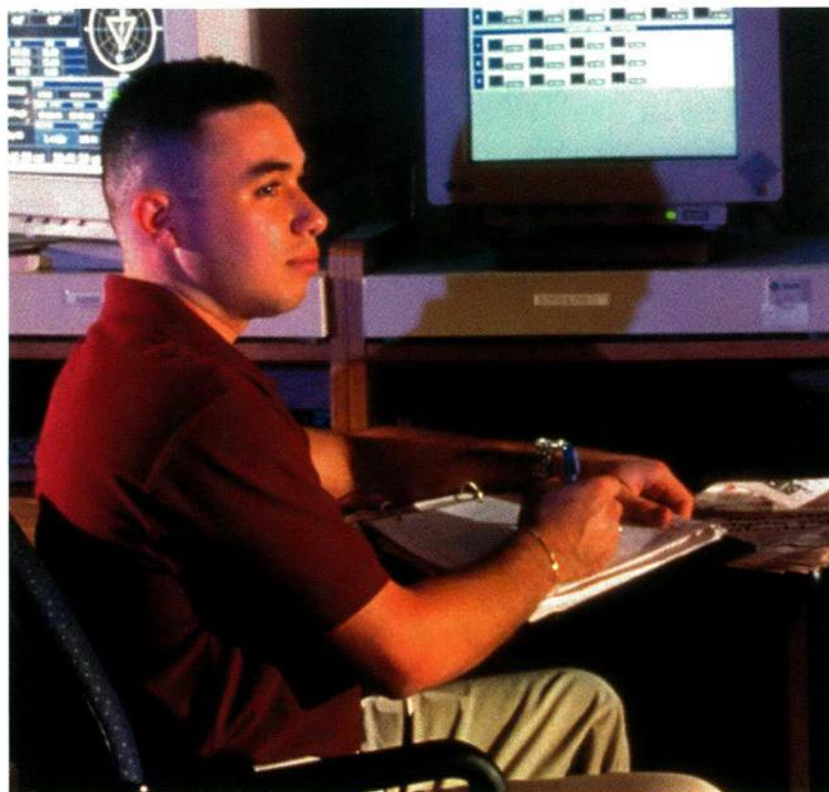
But long before movie-goers ever heard of someone like Cullers, Project Phoenix had begun searching for signals coming from sun-like stars within 200 light-years of Earth. Phoenix focuses on the microwave region (between 1,000 and 3,000 megahertz) of the radio spectrum, where the cosmic background is the quietest and where a weak alien signal is most likely to be heard. The system's computers simultaneously analyze 28 million one-Hertz-wide channels (eventually covering all two billion channels in the microwave window for each star) while looking for narrow, artificial signals.

The Project Phoenix team uses the 1,000-foot (305 meter) radio telescope at Arecibo, Puerto Rico, for two three-week observing sessions each year. Cullers occasionally travels there during the observations to get a feel for how signals from terrestrial sources interfere with the search. The amount and kind of interference changes each year, and his algorithms must account for it. "Rejection of unwanted signals is probably at least as big a part of SETI as detection of the desirable," he says.

As a check against terrestrial interference, the Phoenix team calls on a second radio telescope at Jodrell Bank in England. "What's unique about Phoenix," says Tarter, "is that we process our data in real time." That's

"Rejection of unwanted signals is probably at least as big a part of SETI as detection of the desirable."

Arecibo telescope operator Gerson Ortiz takes notes as he monitors incoming signals.



where the second telescope, along with a follow-up detection device designed by Cullers, comes in. Once a signal is identified at Arecibo, Jodrell Bank astronomers tweak the detectors to optimize the chance of their antenna detecting it also.

"There is an ideal way to detect any signal," says Cullers. "If you know the exact waveform (signal strength per channel) of the incoming signal, you multiply the signal by that same waveform. This effectively squares the incoming waveform.

Still, multiplying incoming signals by every possible waveform at every possible starting time at every possible frequency is computationally impossible at present, according to Cullers. Instead, his algorithms simplify the number and kinds of computer calculations by pruning from further study channels that show no evidence of excess signal strength in early tests. This reduces the amount of memory needed and speeds up the calculations.

Future Searches

So far, Project Phoenix has observed more than half of its planned thousand target stars, and team members expect to continue until the ATA comes on-line. But even with Cullers's clever algorithms, the search for alien signals — and its analysis of millions of radio channels each second — requires enormous amounts of computing power. "You've got a lot of frequencies and lots of stars," he says with considerable understatement. "It's a huge data-processing task."

Computer power is growing exponentially, increasing by a factor of 10 every five years, says Cullers. At that rate, computers will be a trillion times more powerful in just 60 years. Future searches will need that kind of power to crunch the tremendous amounts of data, notes Cullers.



Above: Kent Cullers's trained ears instantly recognize familiar voices as well as aberrant radio transmission signals. **Below:** An aerial view of Arecibo shows the 900-ton receiver suspended 450 feet (137 meters) above the curved, focusing-antenna's surface.

"SETI is filled with a bunch of skeptics who say, 'Prove it's real and not one of the zillion other things it could be.'"

They'll also need larger radio telescopes to gather signals from increasingly distant stars. Cullers is currently working on signal detection algorithms for the Allen Telescope Array (see sidebar on page 60), which astronomers hope to have in operation by 2005. Cullers is also studying a highly speculative radio telescope that, in theory, would



LISTENING TO NORTHERN LIGHTS

"Old-time aurora hands get so mystical they claim you can hear it," explains Kent Cullers, describing a five-day aurora trip to southern Iceland (outside Reykjavik) last February. A busman's holiday for Cullers, the travelers included Frank Drake of the SETI Institute and Chris McKay of NASA-Ames. The group visited many popular tourist sites, but the main attraction was the night sky. While the others carried cameras and telescopes, Cullers brought a radio.

Listening to the buzz and whistles of radar wave echoes allows Cullers to "see" the curtain of energy high in the ionosphere. In the mid-1970s he gathered computer data on the phenomenon below the Arctic Circle in Chatanika, Alaska. Part of his graduate student work involved bouncing high-power radar signals

off the upper ionosphere in order to measure the motion of plasma across large regions. Cullers wrote his doctoral dissertation on aurorae.

Observing auroras in Iceland is relatively comfy. "It was much colder in Alaska," he recalls. While his travel companions gazed at the spectacular display overhead, Cullers "imagined" the curtain of light with a shortwave radio pressed to his ear. The aurora chops up human voices with a hum.

"Normally, signals coming to the North Pole sound fluttery as aurora conditions begin — like this," says Cullers, imitating the interference noise. As the frequency dial moves up and down, he traces the auroral effect on the radio end of the electromagnetic spectrum. "I hear 'ooos' and 'ahhs' about the time the hum becomes intense," he says.



Judith Marx Golub

Kent Cullers listened to this auroral display on February 25, 2001, near Reykjavik, Iceland.

"When I hear signals from distant regions," says Cullers, "my mind goes out there. I try to ride those waves, extend my senses into a realm they've never been, hear songs from a cloud of gas." — *Diane Richards, Manager of Development Communications for the SETI Institute*

be able to observe all of the sky all of the time over a wide range of frequencies — a kind of radio fly's eye.

"We think we know how to build it," Tarter says. "We just don't have enough computing power on the planet to do so." Nevertheless, Cullers has begun working on a much smaller version, trying to figure out how its beams work and how to do the signal processing. "My plate is full," he laughs. "I'm happy."

Champagne, Anyone?

So what happens if Project Phoenix actually finds an extraterrestrial signal? "There is a bottle of champagne on ice," Cullers says. "It gets changed from time to time. We don't want the champagne to go bad by the time we succeed."

For Cullers, the most exciting aspect of a successful detection is that the signal must originate from a civilization much more advanced than ours. A younger civilization wouldn't have developed radio yet, he argues, and so, couldn't be detected.

"You can find out some interesting things right away, given detection," Cullers notes. Researchers can watch how the signal frequency changes over time to determine how fast the home planet rotates and orbits its star, as well as other data.

"You can even begin to speculate as to whether the chemistry of the star or other object you detected is anything like our chemistry," he says.

But, Cullers adds, there's a big difference between the signal strength and the amount of information needed to decode a message — decoding may require more telescope gathering power than is currently available; while we may be able to prove that E.T. exists, we may not be able to discern what, if anything, it's saying.

"You might think that SETI is full of people who say, 'I found E.T. — prove I haven't.' In fact, it's filled with a bunch of skeptics who say, 'Prove it's real and not one of the zillion other things it could be,'" he says. For Cullers, an actual detection isn't as important as the search process. He thrives on the intellectual challenges SETI presents. "Getting there is half the fun," he insists.

Cullers fully expects the SETI search to take a long time. "My ambition is to start the search out right," he says. "If it completes in my lifetime, hey, I'm ecstatic and I drink the champagne. On the other hand, if I simply do my piece of the search correctly, and lay out a path for the technology to do it better, then I will have accomplished a lot."

Others might say Cullers has already accomplished a lot. As Frank Drake said of his work on SETI algorithms, "Kent said that remarkable things were possible — and then he did them." **A**

Frequent Astronomy contributor Sally Stephens, of San Francisco, California, is a former editor of Mercury magazine.

"My ambition is to start the search out right. If it completes in my lifetime, hey, I'm ecstatic and I drink the champagne."

sky Show

december

Saturn and the sun slip behind the moon.

by Martin Ratcliffe and Alister Ling

► The solar system serves up a schedule of nonstop observing pleasures this December. Topping the bill is a solar eclipse, followed closely by the dependable Geminid meteor shower, an easy comet and asteroid for binoculars, and an occultation of Saturn. In case that's not enough, enthusiastic skywatchers will find more treats in the deep sky.

Comet LINEAR WM1 is predicted to crest at 4th magnitude this month in the early evening sky, which means even the unaided eye may glimpse it from a dark, rural site during the first two weeks of December. With some luck, an outburst will make it even brighter and visible to casual observers in the city.

Blazing speedily across the sky, dramatic shooting stars are the hallmark of the annual Geminid meteor shower. Bundle up well against the cold on the night of Thursday, December 13. City-bound observers can count on seeing 15 to 20 meteors per hour, but those observing from darker sites should be able to quadruple that count.

Hope for clear skies on solar eclipse day, December 14, when the moon will block out part of the sun for much of the Western Hemisphere. A dramatic sunset eclipse is lined up for the eastern seaboard, but if you want more, head to



A partial eclipse punctuates this sunset over a mountainous foreground. Wanda Walker

the Nicaragua/Costa Rica border to witness the spectacular "ring of fire" sunset. One warning, though — you will need to use proper filters at all times because the moon will not block out all of the sun's literally blinding light.

The ringed-wonder Saturn is the planet of choice this month. Even through the smallest telescope you can follow the planet's largest moon Titan along its huge orbital loop. Closer in to the ringed one, watch for the shadow of Saturn's gaseous orb to grow outward onto the rings. On December 3, Saturn forms a line with Earth and the sun, an event that astronomers refer to as an "opposition." A unique event will occur on the night of December 27 for North Americans when the almost full moon passes in front of Saturn — a repeat performance of the November 30 incident when North America and Europe had ringside seats to this spectacle. Cross your fingers for good weather on both nights.

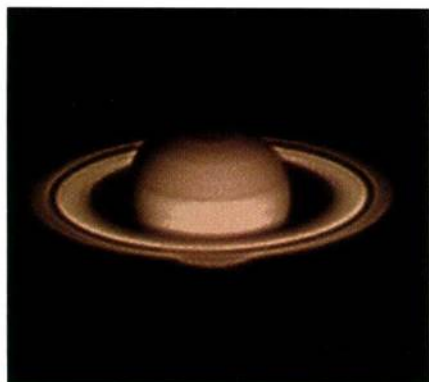
Winter solstice will be celebrated around the Northern Hemisphere on December 21. The exact moment that Earth's south pole tilts most toward the sun is 2:21 P.M. EST, making it the shortest day of the year for those north of the equator.

You should be able to glimpse the penumbral eclipse of the moon on Sunday night December 29 and the following night. The bottom edge of the lunar disk will dip through the outer partial shadow cast by Earth. The eclipse's maximum occurs near 5:30 A.M. EST and 2:30 A.M. PST, when the moon's lower half will turn a pale yellow-gray — a bit like a harvest moon color, but with Earth's satellite much higher in the sky.

Keeping tabs on the brightest asteroids has never been easier. Simply point your binoculars eastward to the bottom of the Hyades star cluster near the bright orange-red star Aldebaran. Vesta, the fourth asteroid ever seen by human eyes, will masquerade just one binocular field to the upper right of the cluster.

Don't forget to watch the southwest sky for rusty Mars. It will race eastward against the stars and fade as the weeks go by. At 120 million miles away, the Red Planet will be far enough to make its surface details elusive to even the best telescopes and digital imaging equipment.

The Ringed Planet is a remarkable sight in any scope this month. John Chumack



2001 December

- 3 The moon passes 1.6° north of Jupiter, 6 A.M. EST
Saturn is at opposition, 9 A.M. EST
- 4 Mercury is in superior conjunction, 5 P.M. EST
- 6 The moon is at perigee (229,980 miles from Earth), 5:43 P.M. EST
Pluto is in conjunction with the sun, 11 P.M. EST
- 7 Last quarter moon is at 2:52 P.M. EST
- 13 Geminid meteor shower peaks (page 72)
- 14 New moon is at 3:47 P.M. EST; annular solar eclipse (page 71)
- 17 Saturn passes 4° north of Aldebaran, noon EST
- 18 The moon passes 4° south of Neptune, 2 A.M. EST
Asteroid Harmonia is at opposition, 6 P.M. EST
- 19 The moon passes 4° south of Uranus, 7 A.M. EST
- 20 The moon passes 4° south of Mars, 3 P.M. EST
- 21 The moon is at apogee (251,428 miles from Earth), 8:03 A.M. EST
Winter solstice is at 2:21 P.M. EST
- 22 First quarter moon is at 3:56 P.M. EST
- 28 The moon passes 0.2° north of Saturn, 3 A.M. EST (page 71)
- 30 Full moon is at 5:40 A.M. EST; penumbral lunar eclipse
The moon passes 1.2° north of Jupiter, 9 A.M. EST

SUN.	MON.	TUE.	WED.	THUR.	FRI.	SAT.
						
						
						
						
						
						

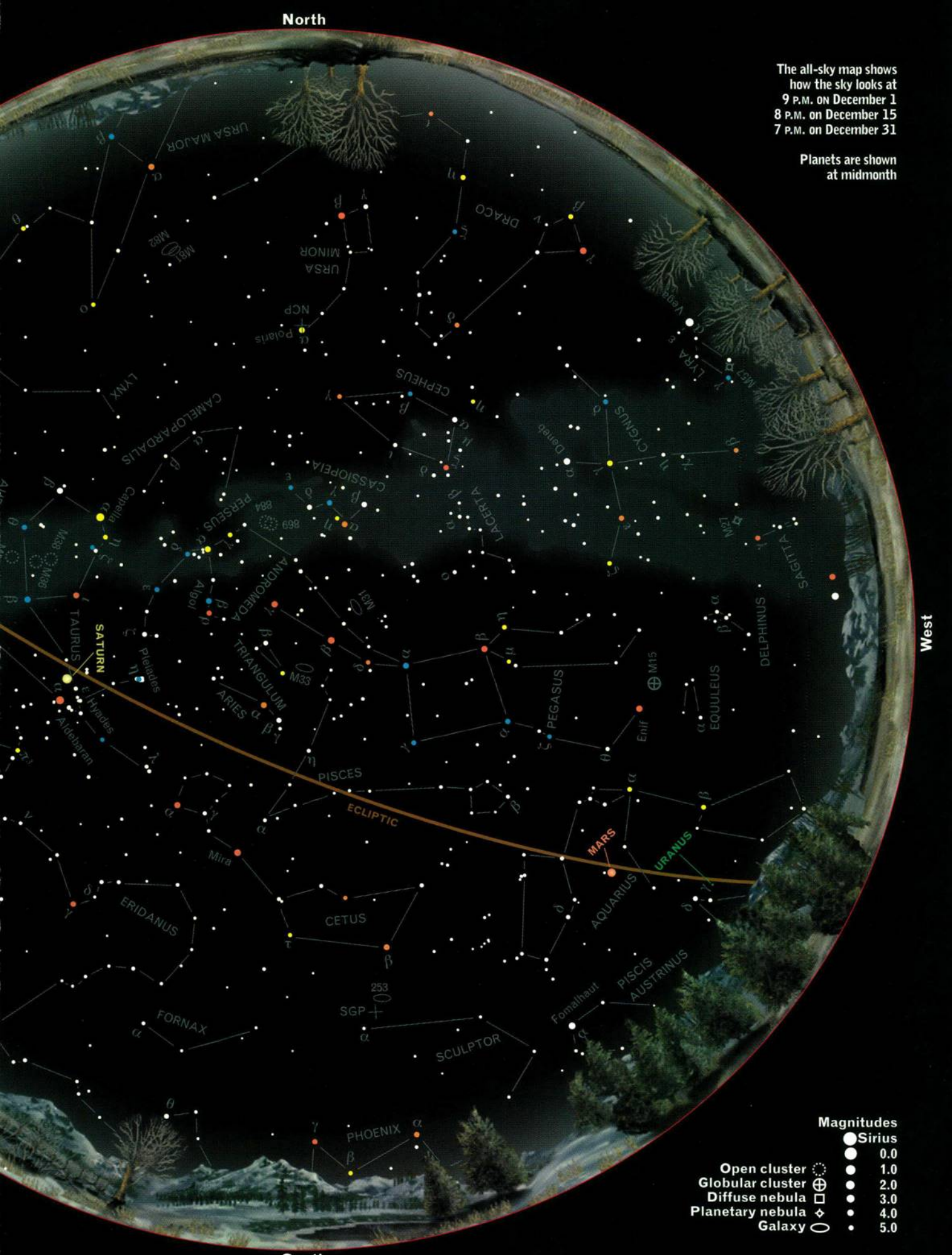
East

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

North

The all-sky map shows
how the sky looks at
9 P.M. on December 1
8 P.M. on December 15
7 P.M. on December 31

Planets are shown
at midmonth



West

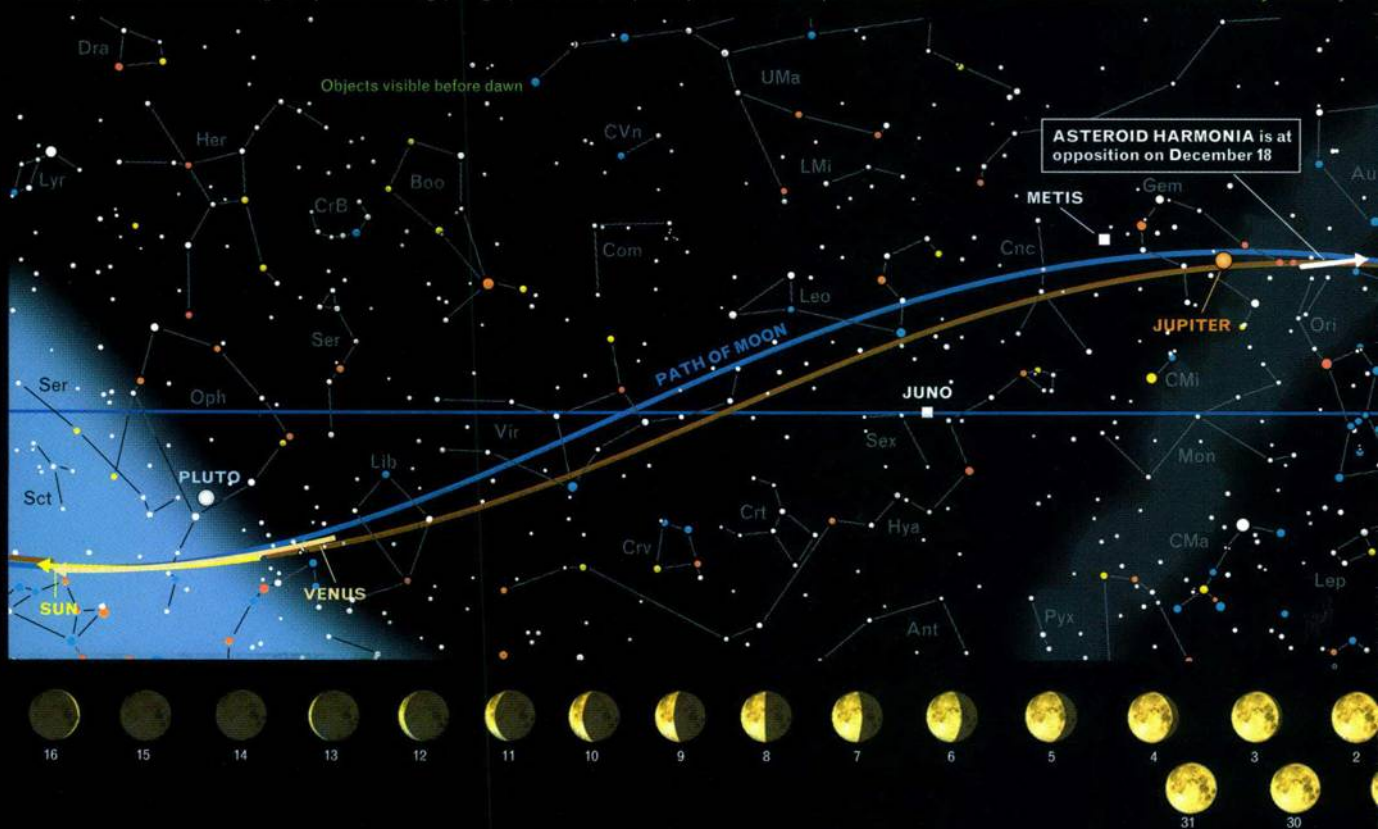
South

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- ⊙ Globular cluster
- Diffuse nebula
- ◇ Planetary nebula
- Galaxy

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects.

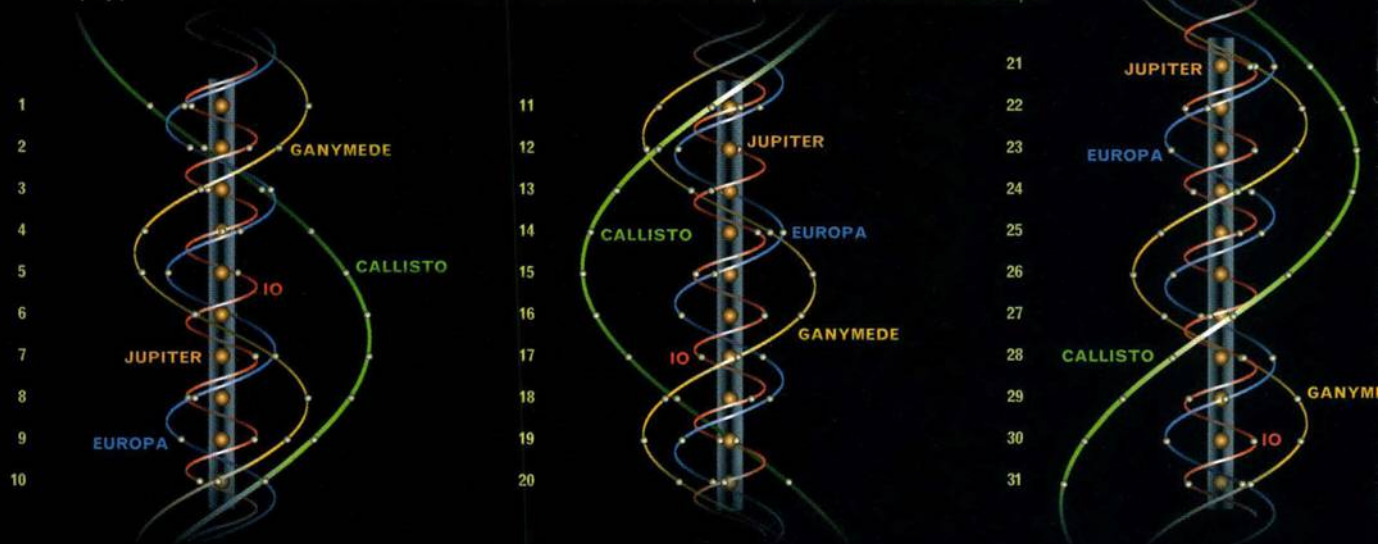


PLANETS

Date	10"	S	W	E	N	MERCURY	MERCURY	VENUS	MARS	JUPITER
December 15						December 15	December 31	December 1	December 15	December 15
Magnitude						-0.9	-0.8	-3.9	0.6	-2.7
Angular Size						4.7"	5.4"	10.0"	6.8"	46.6"
Illumination						99%	88%	98%	87%	100%
Distance (AU) from Earth						1.424	1.248	1.669	1.371	4.228
Distance (AU) from Sun						0.457	0.389	0.723	1.409	5.165
Right Ascension (2000.0)						17h54.1m	19h45.2m	15h44.3m	22h26.7m	6h55.9m
Declination (2000.0)						-25°13'	-23°22'	-18°58'	-10°52'	22°47'

Jupiter's Moons

Dots display positions of Galilean satellites at 11 P.M. EST on date shown. South is at top to match the view in a telescope.



during the month.



To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.



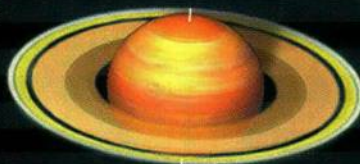
ER
er 15



SATURN

December 15

-0.4
20.5"
100%
8.102
9.065
4h36.8m
20° 12'



URANUS

December 15

5.9
3.4"
100%
20.481
19.987
21h37.4m
-14° 56'

NEPTUNE

December 15

8.0
2.2"
100%
30.799
30.096
20h37.0m
-18° 27'

PLUTO

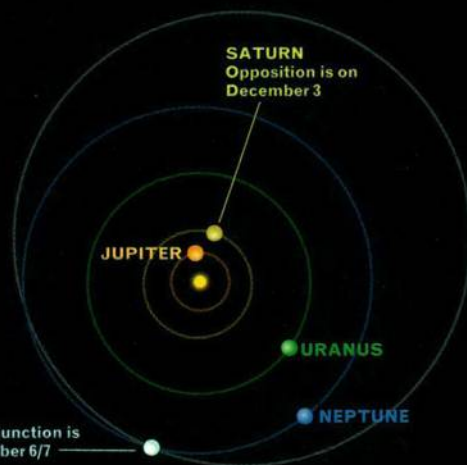
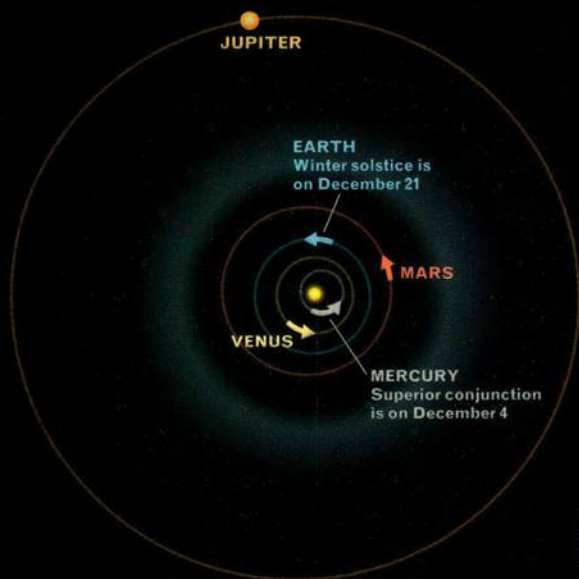
December 15

13.9
0.1"
100%
31.416
30.455
17h00.9m
-12° 56'

m

The Planets in Their Orbits

Arrows and dots show planets' positions during the month.



DE

Comet LINEAR WM1 Sails near Southern Splendors

Seen from Charles Messier's Paris observatory in wintertime are three celestial beauties low on the southern horizon that escaped reference in his famous catalog. Had they been over his head, these two galaxies and one bright globular cluster would be prime targets for today's Messier-object hunters. If you can find the springtime galaxy M83, then you should have no problem finding these other gems.

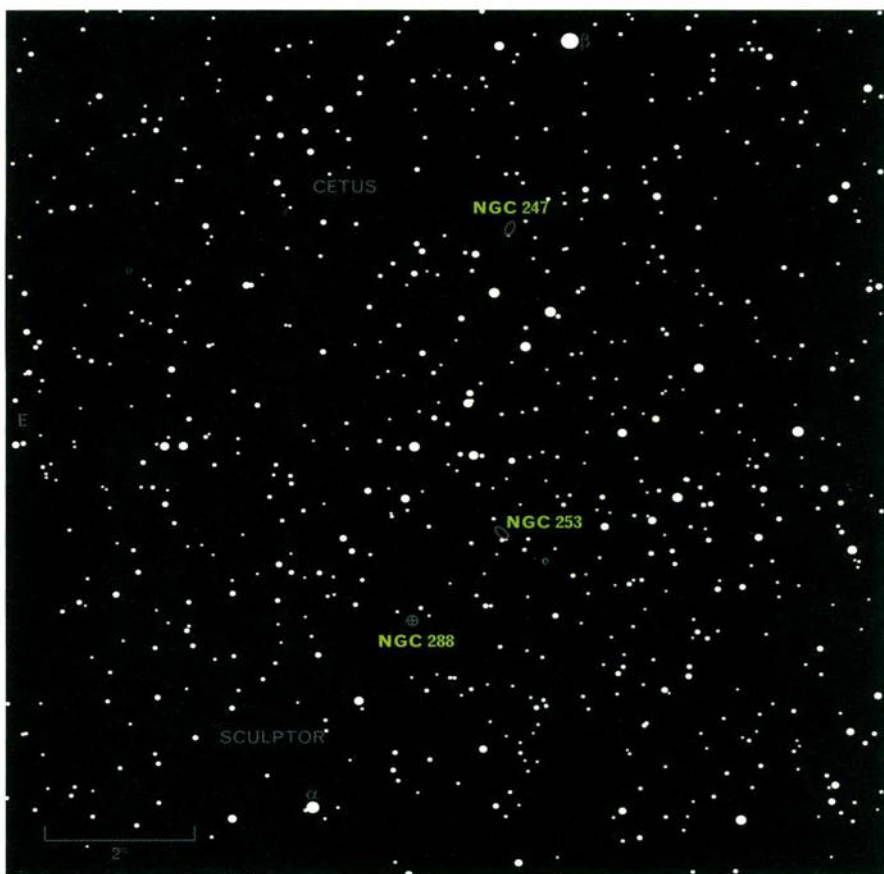
When you're on the lookout for Comet LINEAR WM1, you'll need a dark sky with a clear southern horizon. Early in the evening, two bright stars lie near the comet, 1st-magnitude Fomalhaut, to the lower right, and Beta (β) Ceti, somewhat fainter at 2nd magnitude and a bit to the upper left.

Only half a binocular field south of Beta Ceti is NGC 247, a large cigar-shaped spiral galaxy, tilted about 30° from edge-on to our line of sight. NGC stands for *New General Catalogue*, a 19th-century compendium of most of the deep-sky objects known at the time.

At first, use your telescope on low power to sweep up NGC 247's huge elongated form — at $20'$ long, it's two-thirds the size of the moon.

From mid-northern latitudes, a telescope is a must to see the NGC 253 and NGC 288 duo. If you ever travel south of the equator, the pair is an easy binocular sight from a dark sky. Drop south another 4° , more than half a binocular field of view, from NGC 247 and you'll land on the brighter, elongated spiral NGC 253. It was discovered by Caroline Herschel (William's sister) from England — just goes to show that a little determination can pierce England's legendary winter cloudiness.

Spanning $25'$ by $7'$ of sky with a magnitude of 7.1, NGC 253 is the southern rival of the famous starburst galaxy M82 in Ursa Major. With a 12-inch or larger scope, expect to see a mottled glow with dark patches. NGC 288, a loose globular cluster, lies 2° southeast of NGC 253. A small telescope should capture its diffuse glow, but a bigger scope will reveal its brighter dozen or so stars in front of a granular haze.



Saturn and the Sun Slip behind the Moon

The two giant planets of our solar system, Jupiter and Saturn, are on display each night during December. The moon hides Saturn, once at the end of November and again a month later. In addition to this planetary activity in our night sky, the daytime hours will host a partial eclipse of the sun.

An annular eclipse occurs on December 14 for observers in the vicinity of Nicaragua and Costa Rica. The moon will not totally block the sun in this event because the moon is slightly farther away from Earth in its monthly orbit — a positioning responsible for the impressive “ring of fire” effect around the moon during such an eclipse. (Warning: This annular eclipse is not safe to view with the naked eye). In North America the eclipse will only be a partial one. Most of the eastern part of the United States will witness an amazing sunset on the 14th as the partially obscured sun dips below the horizon. Those observers in the deep southeastern U.S. should see a more robust partial eclipse. Check the diagram for information relevant to your area.

A crescent moon stands underneath **Mars** on December 20, with only eight moonwidths separating them. Mars has now dimmed to magnitude 0.6, shining in a region devoid of any bright stars and is only a mere shadow of its glory last summer. However, remember that Mars will make a bigger, brighter comeback in 19 months. You might also spot Fomalhaut, the 1st-magnitude star in Piscis Austrinus, standing half as high as Mars above the horizon this month.

Two other planets linger in the evening twilight: **Uranus** and **Neptune**. Neptune becomes increasingly difficult to see because of the encroaching twilight, but Uranus remains an easy binocular object in eastern Capricornus. Search for the magnitude 5.9 Uranus a little more than 2° to the right of Deneb Algedi, also known as Delta (δ) Capricorni.

While Mars and the more distant planets set in the west, **Saturn** rises in the east. On December 3 it lies directly opposite the sun in the sky, which



leaves the Ringed Planet standing due south at midnight. This point of opposition also means that Saturn is visible all night.

Two rare events occur a month apart when the moon hides Saturn in an occultation. On November 30, visible from most of North America, the full moon will close the drapes on Saturn. The brightness of the moon will make viewing the event a little more difficult, but it is spectacular nonetheless. West Coast observers will miss Saturn's disappearance but can watch its reappearance following moonrise.

One full lunar orbit later, in the pre-dawn hours of December 28, the moon passes in front of Saturn again as seen from North America. The entire event, both disappearance and reappearance, is visible from all of the United States, Hawaii, regions of Canada, and northern Mexico. This time the moon is two days short of full, and while it's still very bright, Saturn will disappear behind the dark limb of the moon.

Exact times of disappearance depend on your geographic location. Approximate times for eastern, central and western United States are at 4 A.M. EST in New York, 2:40 A.M. CST in

Jupiter (upper left) appears to dance atop the aurora borealis. Jim Pfeifferberger

Kansas City, and 12:10 A.M. PST in Sunnyvale, California. You can get more details about this event by visiting the website of the International Occultation Timing Association at <http://www.lunaro occultations.org>.

Throughout December, Saturn appears brighter and larger than during last year's apparition because the planet is slowly approaching its 2003 perihelion. This also coincides with the widening of its rings as seen from Earth. The Ringed Planet shines at magnitude -0.5 at opposition among the stars of Taurus the Bull. Saturn's normal motion is easterly against the stars, but this month its path is westerly. This backward, or retrograde, motion is a result of Earth overtaking Saturn as they orbit the sun. By December 12 Saturn reaches a point less than 4° north of Aldebaran, the brightest star in Taurus. Saturn lies slightly more than eight astronomical units from Earth (1 AU = 93 million miles). Through a telescope Saturn's globe spans 20".

Observers who have watched Saturn's rings closely will notice that

the planet's shadow on the rings has disappeared, resulting from the planet's opposition. By New Year's Day the shadow will reappear on the eastern side of the planet. Features in Saturn's atmosphere are difficult to trace, but once in a while a white spot may materialize. Tracking the movement of such features enables one to determine the planet's atmospheric rotation speeds. Timing the moment that such spots cross the planet's central meridian is helpful in this regard.

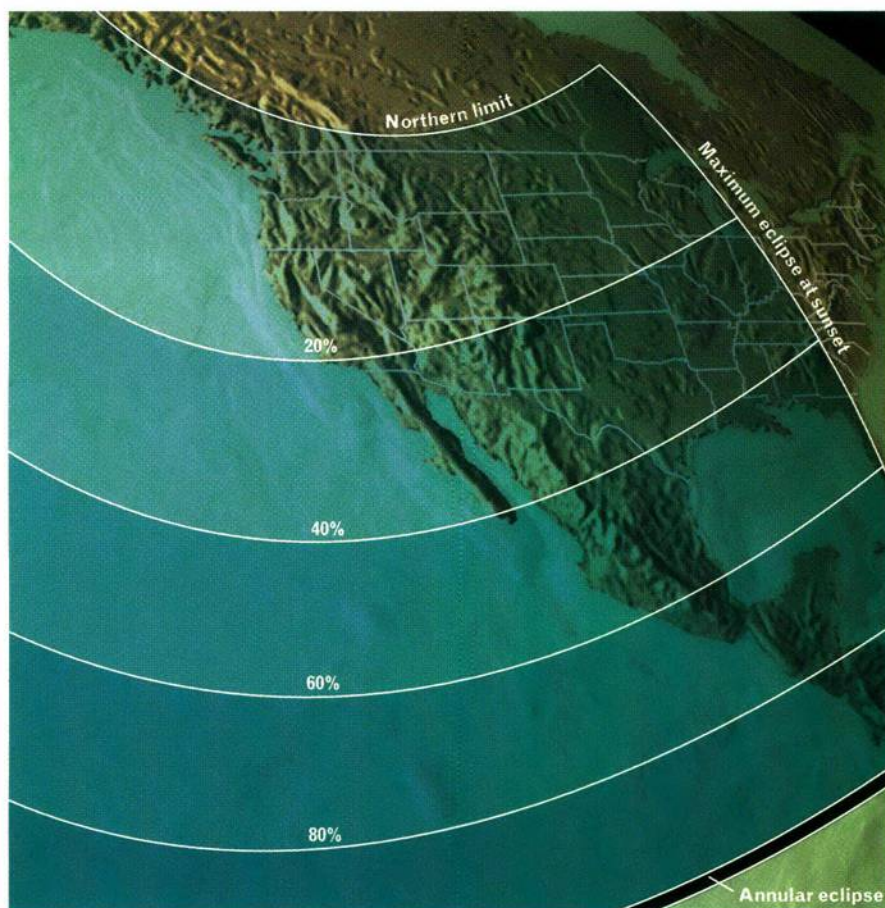
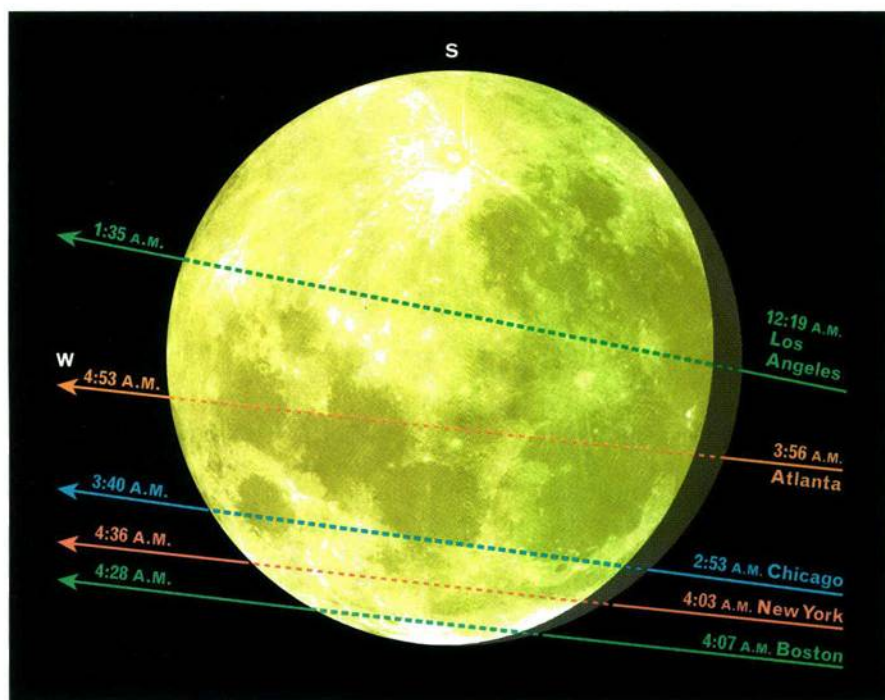
Saturn's moons are plentiful, with Titan being the easiest and brightest to spot. For a closer look at the array of moons on show this month, check "Meteoroids and Moons."

Following Saturn above the horizon is **Jupiter**. The solar system's largest planet rises two hours after the Ringed Planet. Jupiter lies centrally in the constellation Gemini the Twins. The two 1st-magnitude stars Castor and Pollux dominate this constellation. Jupiter dramatically changes the appearance of the group, shining at a dazzling magnitude -2.7 . The planet reaches opposition on New Year's Day.

Jupiter achieves a relatively large size of $47''$ across in December and lies 4 AU from Earth. Because of this, observers with even small telescopes should see small features in the planet's cloud deck. Also, features such as the Great Red Spot and the dark equatorial belts should be easy to see if the timing is right. By the end of the year Jupiter is climbing in the east-northeast right after sunset and is visible all night. It passes almost overhead an hour or so after midnight — a perfect location for examining the giant planet in detail. In fact, almost 13 hours of darkness should allow for viewing most of Jupiter in one night.

Jupiter's cloud bands circle the planet in roughly ten hours. With careful noting of the position of certain features, even novice observers should detect noticeable changes.

Mercury and **Venus** are hidden by the sun most of the month. Mercury then appears in the sky for southerly observers but not for those positioned in the Northern Hemisphere.



Geminids

A new moon coincides with the peak of the Geminids, which creates ideal conditions for observing this historically robust meteor shower. From darker locations, up to one meteor per minute might be glimpsed during peak activity, early in the morning of December 14. Meteors from this shower tend to be bright and medium speed. The radiant, or point from which meteors appear to emanate if their tracks are traced backward, lies just north of Castor, the northernmost of the two bright stars in Gemini. Such a position makes the shower visible for a great portion of the night, although shower rates will peak only a few hours after midnight when the radiant is at its highest point in the sky.

Penumbral Eclipse of the Moon

On December 30 the full moon passes into the penumbral shadow of Earth. Look for a slight darkening of the moon's southern limb around 4:29 A.M. CDT, the time of mid-eclipse. This effect is often so faint, though, that casual observers won't notice anything peculiar. The moon will not enter the full shadow of Earth, therefore no partial eclipse will occur. The effects of the penumbral shadow may be detected about 45 minutes before and after the mid-phase, although technically the eclipse lasts about four hours.

Saturn's Satellites

With Saturn visible all night long, it's a good time to track some of the planet's satellites. Many saturnian moons are visible through small telescopes. Titan, the brightest of all the moons, will be the most obvious one. Shining at magnitude 8.3, Titan orbits Saturn once every 16 days and begins the month approaching its eastern elongation on December 4. Four days later Titan lies due north of the planet, and four days after that it will move through its western elongation. Each four-day period sees Titan move one-quarter of its orbit around Saturn.

Close inspection of the region inside Titan's orbit reveals a number of other satellites, especially through tele-

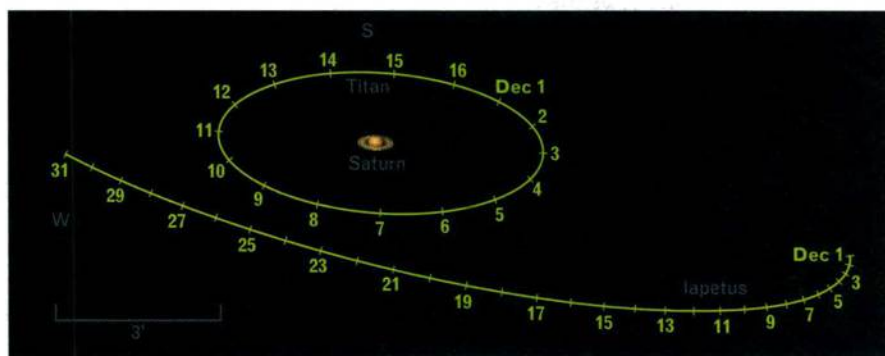
scopes 8 inches or larger. The brightest of these inner moons is Rhea, which orbits Saturn in 4.5 days. Rhea moves through roughly one-quarter of its orbit around Saturn each consecutive night. On December 4, when Titan lies to the east, Rhea appears about four Saturn-disk diameters to the west of the planet. Just two nights later it joins Titan on the eastern side of Saturn.

Three other inner moons are relatively easy to spot: Enceladus, Tethys, and Dione. Their magnitudes are 11.7, 10.2, and 10.4, respectively, and they orbit Saturn in 1.4 days, 1.9 days, and 2.4 days, respectively.

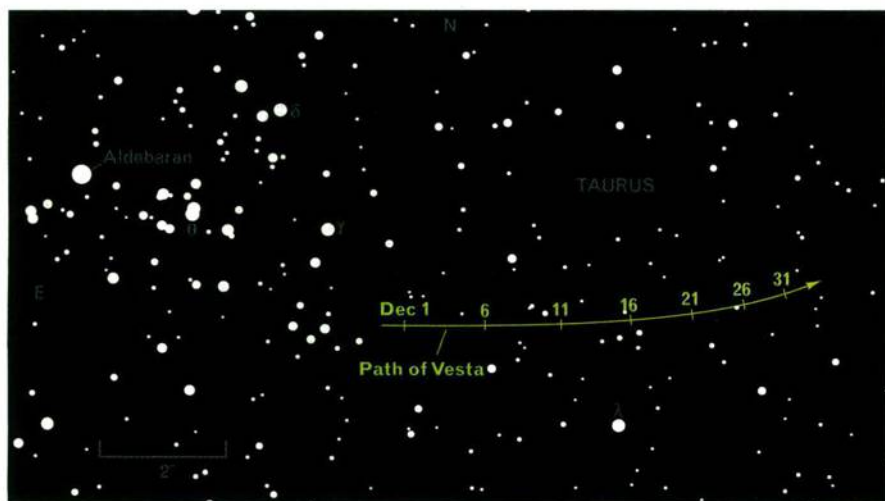
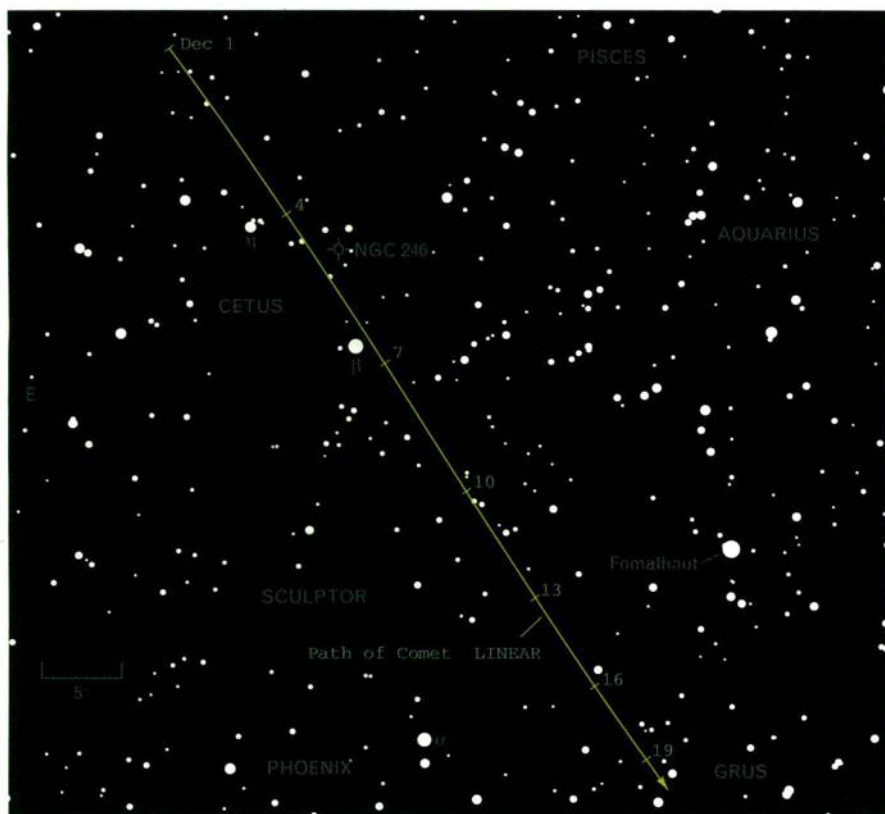
Iapetus used to be the most mysterious of all Saturn's moons. Its relatively long 79-day orbital period helped to reveal that this peculiar moon shines at

magnitude 10.2 at its western elongation and dims inexplicably to magnitude 11.9 at its eastern elongation. The visit by the Voyager spacecraft solved this mystery once and for all. Close-up photographs of the moon reveal that half of Iapetus is covered with black material, the origin of which remains a puzzle.

During December you can observe the brightening of Iapetus. It lies at eastern elongation on December 3 at magnitude 11.9. By December 23, as Iapetus passes north of Saturn, it will shine nearly one whole magnitude brighter. The small moon continues to brighten for the remainder of the month, when, in the early part of the New Year, you can view the enigmatic Iapetus at its brightest point.



Comets and Asteroids



LINEAR WM1 Delights Skywatchers

In what should be a great show, LINEAR WM1 rides above the southern horizon during prime evening hours. If predictions hold out, this dirty snowball should be visible to the naked eye at some sites. The moon's interfering light will be absent for the two weeks that favor viewing from the

Northern Hemisphere.

From the city, LINEAR WM1 will most likely appear as an elongated fuzzball through binoculars, a bit like M31, the Andromeda Galaxy. Look for a fainter tail pointing to its left. Switch back and forth between M31 and LINEAR WM1 so you can compare and contrast their features. Do they

brighten rapidly into a nearly stellar core? Are there any soft or sharp edges?

Point a telescope at the comet and try a range of magnifications. Some scientists have predicted that the nucleus might split into fragments. If such an event happens, you might see a bright outburst as sunlight exposes fresh cometary material.

The best time of night for observing LINEAR WM1 will be just as it gets dark. The comet starts off December halfway up the sky in northern Cetus but then will plunge rapidly southward, past planetary nebula NGC 246 and Beta Ceti into Sculptor. Remember that the closer toward the horizon you observe, the more atmosphere and dust particles you have to contend with in trying to glimpse subtle details and all but the brightest of tails.

If you see two tails, the straight one is called the gas or ion tail, blowing directly away from the sun in the solar wind. The broader, fan-shaped tail is from sunlight scattered by ejected dust. This dust spreads out along the comet's orbit, which usually appears curved from our point of view.

Vesta Shines Brightly

As the third largest rock in the inner solar system, the asteroid Vesta often reveals itself to even the unaided eye. This year the 300-mile-wide (500-km) chunk of space rock won't be so readily apparent, but at magnitude 6.5 it should be a snap to locate with binoculars even from larger urban areas.

Rising in the east alongside the sparkling V-shaped Hyades star cluster, Vesta lies to the upper right by 6°, or about one binocular field of view away. Remarkably, only four other background stars compete with Vesta for the brightest object in the field. All you need to do is use a chart to orient yourself, then simply note which star seems out of place ... you've found Vesta. **A**

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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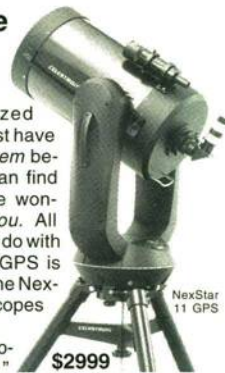
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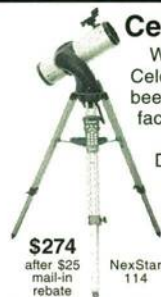


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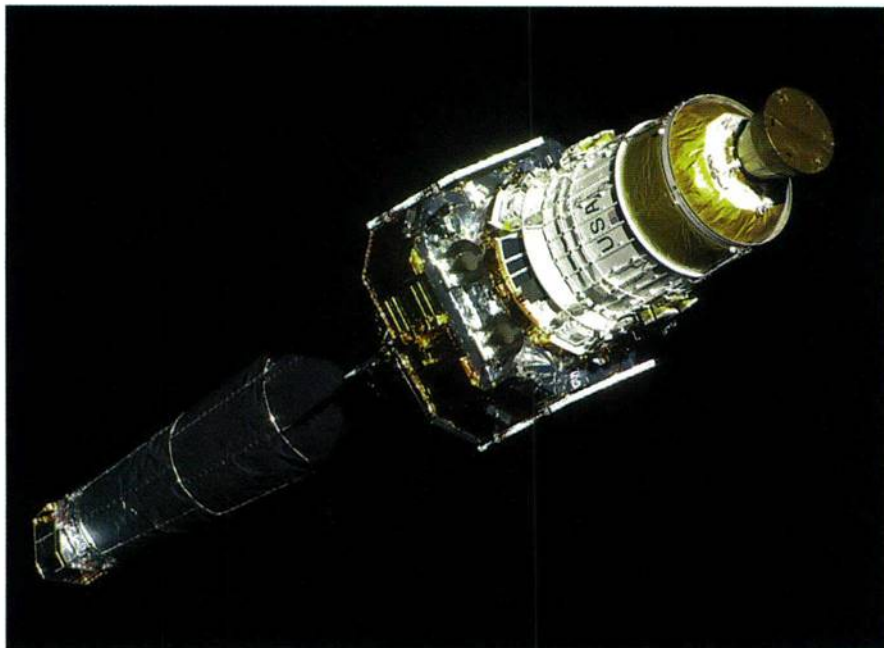
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X-ray Vision, Our Aging Universe, Meteor Mysteries



How does the Chandra X-ray telescope work? What are its limitations? — Caroline Khor, Mt. Annan, NSW, Australia

X-ray telescopes such as NASA's Chandra X-ray Observatory use mirrors that are very different from the kind used in optical telescopes. X-ray photons pack hundreds to thousands of times more energy than photons of visible light. Therefore, when an x-ray photon strikes the surface of an ordinary, concave-shaped optical mirror, it passes through it like a bullet fired through tissue paper.

Using a technique developed by German physicist Hans Wolter in the 1950s, the designers of Chandra and other x-ray telescopes build tubular mirrors that reflect x rays at grazing angles, like skipping stones across a pond. In the case of the Chandra observatory, it carries four pairs of

The 45-foot, high-flying Chandra is the largest satellite ever launched by space shuttle. NASA

barrel-shaped mirrors nestled inside one another like Russian Matrioshka dolls. The outer mirrors provide most of the collecting area for the lower-energy x rays, whereas the inner mirrors provide most of the collecting area for the higher-energy x rays.

Because x rays pack such high energy, only the most violent, hot, and exotic objects in the universe can produce them in copious quantities. Some of the most luminous x-ray sources include supernova remnants, black holes and neutron stars that are gobbling matter from their surroundings, high-speed particle jets shooting out of the cores of active galaxies, and vast intergalactic clouds of multi-million-degree gas.

The most fundamental limit of x-ray telescopes is the fact that they must be placed above Earth's atmosphere,

which absorbs x rays from outer space. And like their visible-light cousins, the resolution and light-gathering power of x-ray telescopes are limited by their size and optical quality.

Chandra, for example, sports the smoothest x-ray mirrors ever constructed, so it can resolve x-ray sources with unprecedented clarity. The European Space Agency's XMM-Newton X-ray Observatory, on the other hand, has larger but rougher mirrors. XMM-Newton can capture more x rays for spectroscopic analysis, but its imaging resolution is poor compared to Chandra's. X-ray astronomers are currently designing x-ray interferometers, which would use networks of x-ray telescopes to resolve, among other things, accretion disks around black holes. — *Robert Naeye, author of Signals from Space: The Chandra X-ray Observatory (Turnstone Publishing Group, 2000)*

How does the recent discovery of the most distant known supernova affect cosmology and the age of the universe? — Tony Marsh, Ascot, Berkshire, United Kingdom

The discovery of SN 1997ff (see *AstroNews*, July 2001, page 20) at a redshift of 1.75 (meaning its light has been shifted by a factor of 2.75 toward longer wavelengths) implies that the results presented in 1998 by both the Supernova Cosmology Project and the High-Z Supernova Search Team were correct — that we live in an accelerating universe.

What's more, it appears that the acceleration has only recently begun.



Gravity once ruled the universe. But alas, the crown has since been abdicated to acceleration. Ann Feild (STScI)

From the SN 1997ff results, it appears that the “dark energy,” which is believed to be the cause of this universal acceleration, began to dominate gravity (the major source of earlier deceleration) just a few billion years ago. Based on this and other supernova measurements, our best estimate of the age of the universe currently stands at 14.5 ± 1 billion years. — Peter Nugent, Lawrence Berkeley National Lab

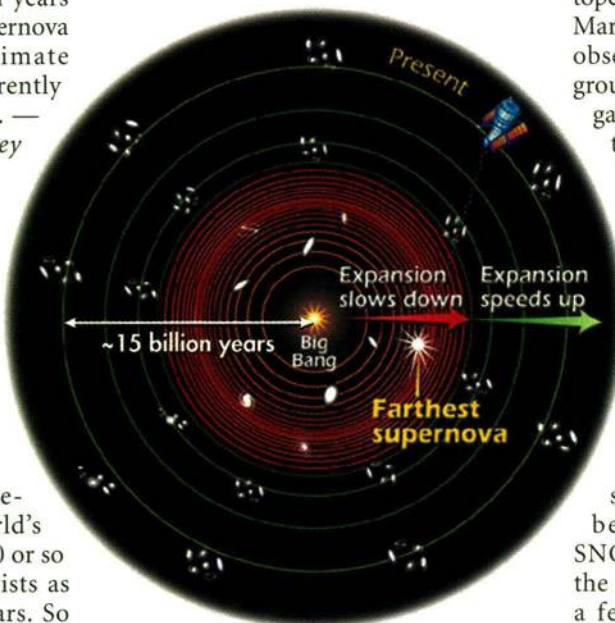
How do scientists determine if a meteorite arrived from Mars, the moon, or elsewhere?
— William T. Smith, Center Barnstead, New Hampshire

Only a few thousand meteorites exist among all the world’s collections. And of these, only 30 or so have been identified by scientists as coming from the moon or Mars. So how do they know?

Most meteorites are not particularly fancy-looking. In fact, most are part of a class called “ordinary chondrites,” which are relatively dark, grainy rocks with an occasional sprinkling of small spherical inclusions.

Despite their name, ordinary chondrites are considered to be extraordinary specimens, as they have chemical abundances very close to that of the sun. They are probably cooled remnants of the solar nebula from which the planets formed. Other

classes of common meteorites contain rock and metal, or just metal, and these are likely the remains of the deep interiors of asteroids or small planets that had segregated into a core, mantle, and crust (a process known as differentiation) and were subsequently smashed apart by impacts.



But a few oddballs have been found over the years that do not look like metal or chondrite meteorites — in fact, they look more like volcanic rocks. By looking at the minerals in these anomalous “achondrites,” studying their textures to find clues about their cooling rates, and measuring the abundances of certain isotopes that indicate formation conditions, scientists have determined that these meteorites came

from large, differentiated planet-sized objects that once had active volcanoes on their surface.

One subset of these anomalous meteorites possesses chemical isotope patterns remarkably similar to those found in the lunar rocks brought back by Apollo astronauts. And yet another subset, called the SNC class, display isotope patterns similar to those found on Mars by telescopic and Viking Lander observations. Some members of this group contain tiny bubbles of trapped gas that is nearly identical to that of the current martian atmosphere.

Because we don’t yet have martian samples to study, the proof is not as conclusive as the case for lunar meteorites, but the available evidence strongly supports the SNCs being rocks from Mars.

How do these rocks get here? Astronomers have shown that impacts can launch materials off planets to escape velocities, littering the solar system with debris that can be exchanged between planets. SNCs were probably blasted out of the martian subsurface by an impact a few hundred million years ago, based on estimates of their space exposure ages. So in addition to rocks from the moon and Mars, meteorites from Venus or Mercury may be waiting to be found.

Someone is bound to be the first person on Mars to find a meteorite from Earth. Now that would be quite a catch. — Jim Bell, Department of Astronomy, Cornell University

Of the innumerable rocks littering the foreground of this panoramic Pathfinder shot, could any be earthling exiles? NASA/JPL





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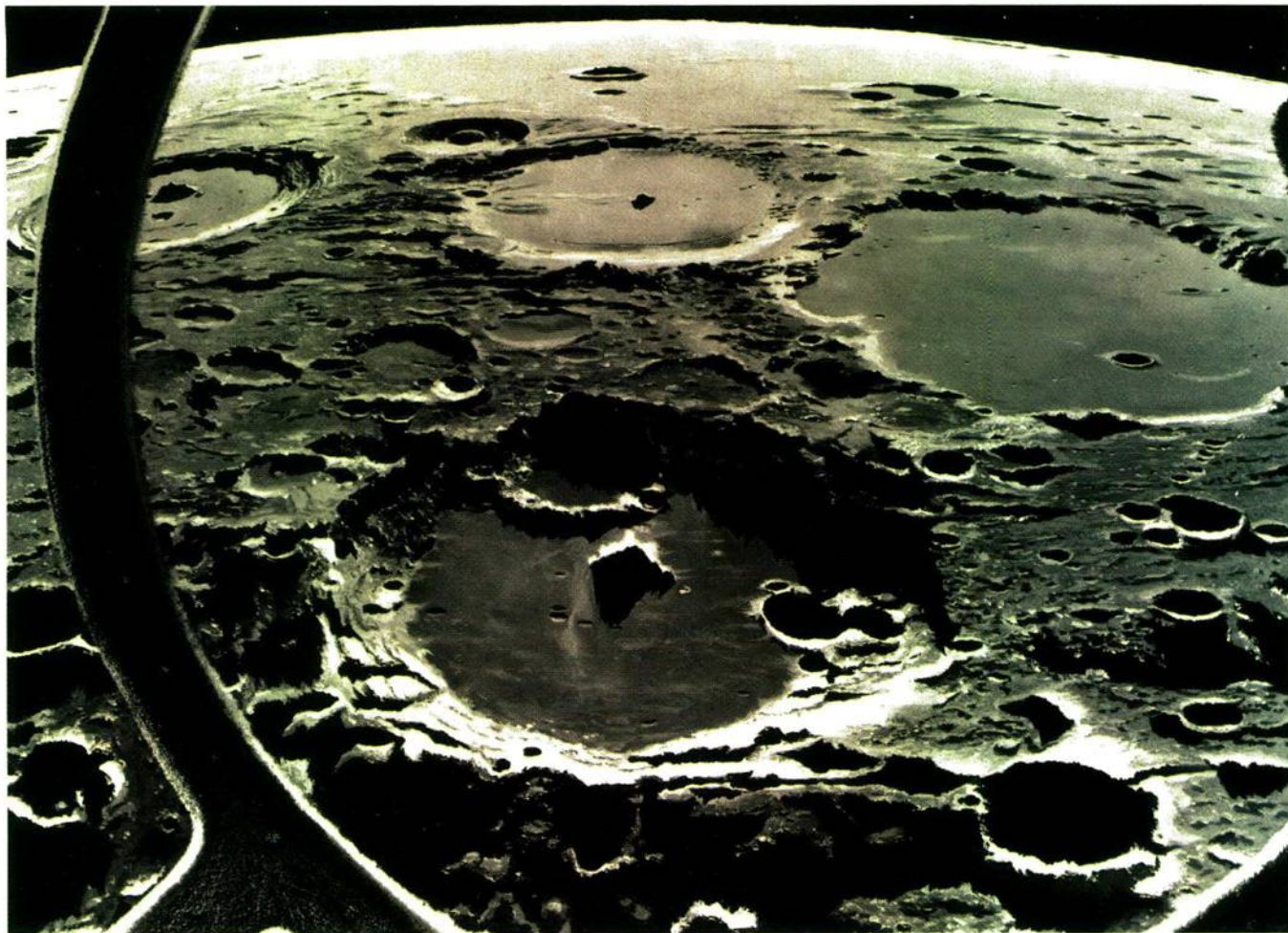
Painting the Universe

*A gallery tour in book form
features the creative works of
Chesley Bonestell, who founded
a new genre and inspired
generations of artists.*

by Andrew S. Fazekas

Chesley Bonestell is often referred to as the godfather of space art. His fascination with space began as a young boy as he gazed through the refractor at the Lick Observatory in 1905. Although his first space-art painting (of Saturn) was destroyed during the great 1906 San Francisco earthquake, Bonestell lived to witness the development of rocketry, the moon landings, and the exploration of Mars. Along the way, he enriched our lives with the images presented in *The Art of Chesley Bonestell*.

All images courtesy of Bonestell Space Art. Images appear in the book *The Art of Chesley Bonestell* by Ron Miller and Frederick Durant III; foreword by Arthur C. Clarke; 256 pages; Sterling Publishing Company, New York, 2001; ISBN 1-855-85884-3; hardcover, \$49.95.



Previous pages: "Saturn as Seen from Titan" (1944); this page, upper: from "The Conquest of Space" (1949), 200 miles (320km) above Albategnius, a lunar crater; right: from "Across the Space Frontier" (1952), separation of the third stage above the Pacific; far right: from "The Conquest of Space" (1949), Earth from 10 miles (16km) above the lunar pole; facing page: from "Beyond the Solar System" (1964), a nova melts an unnamed planet.

The late Carl Sagan once said that he didn't know what other worlds looked like until he saw Chesley Bonestell's paintings. Indeed, Bonestell's artwork breathed life into distant worlds and influenced upcoming generations of scientists, engineers, space enthusiasts, and artists with groundbreaking visions of the universe.

The Art of Chesley Bonestell includes one of the most famous space paintings ever created — Bonestell's revolutionary view of "Saturn from Titan," from his famous 1944 *Life* magazine series. This large format, coffee-table book contains more than 300 other illustrations, 200 of which are reproduced in color. Many never-



before-published paintings, including the original preliminary studies and sketches of his early astronomical works, are also found here.

Authors Miller and Durant offset Bonestell's wonderful images with tantalizing insights into his long, colorful life. Space illustrator Ron Miller is co-administrator, with Frederick C. Durant III, of Bonestell Space Art of King George, Virginia, which manages the rights to Bonestell's artwork. Durant, a long-time friend and Bonestell promoter, was instrumental in developing the space art collection at



the National Air and Space Museum in Washington.

The book's first section includes a biography that contains many unpublished archival photos spanning Bonestell's 98 years. Anecdotes enliven this introductory section, with well-known figures recounting stories of their collaborations. For example, rocket pioneer Werner Von Braun says that he "learned to respect — nay fear — this wonderful artist's obsession with perfection."

The book's second section is a sweeping chronological gallery of







Facing page: from “Rocket to the Moon” (1961), a solar eclipse from our moon; above: “Saturn as Seen from a Moon” (circa 1940); left: from “Across the Space Frontier” (1952), space station, ferry rocket and space telescope above Central America.

Bonestell’s work. Many of his space paintings contain small human figures in the shadows of towering mountains and canyon valleys, in alien destinations like Mimas and Iapetus. It was with settings like these that Bonestell presented alien worlds as equals to exotic locations on Earth.

Bonestell was a prolific artist, and his masterpieces appeared in a wide variety of media, from popular magazines to seminal space-travel textbooks. Today most of Bonestell’s artwork graces private collections that are rarely accessible to the general public.

Although some of Bonestell’s space illustrations appear dated, many of his predictions have come to pass. For instance, the classic *Collier’s* magazine’s 1952 space flight series is represented with fine illustrations of manned expeditions to Mars, space telescopes, wheel-shaped space stations, and winged space shuttles — 29 years prior to the U.S. launching its first shuttle.

Before gaining international recognition for his art, Bonestell worked on significant architectural projects such as the Chrysler building and the Golden Gate Bridge. His unique skills

also made him the highest-paid matte artist in Hollywood in the 1950s. Using his knowledge of camera angles and other motion-picture techniques, Bonestell conveyed to viewers a sense of three dimensions in movies like *Destination Moon* (1950) and *War of the Worlds* (1953).

I recommend *The Art of Chesley Bonestell* for both the longtime Bonestell fan and those just introduced to the Dean of Space Art. Miller and Durant provide a definitive compendium of Bonestell’s most compelling works. This anthology is sure to prove invaluable to any space art collection. **A**

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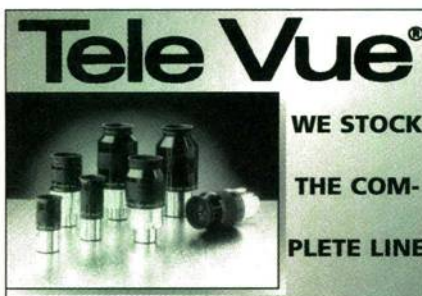
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Cepheus & Lacerta



*The far northern sky
offers a fine range of
sparkling clusters and
bright nebulae.*

by Tom Polakis

Despite the calendar's insistence that we're in the waning days of autumn, the night sky seems reluctant to let go of the previous season. Riding high in the northwest during the evening hours, the northernmost star of the Summer Triangle asterism remains conspicuous. Deneb, the brightest star in Cygnus the Swan, provides a convenient starting point for locating this month's constellations.

Head north from Cygnus and your eyes will alight on a distinct pattern of five stars that resembles a child's drawing of a house with a steep roof. This prominent grouping belongs to Cepheus the King, a constellation that appears circumpolar from most of the United States and all of Canada and Europe. The brightest star in the constellation, 2nd-magnitude Alpha (α) Cephei, marks the southwestern corner of the house and lies some 500 light-years from Earth. The precession of Earth's axis will make Alpha the pole star in approximately 5,500 years.

Cepheus lies along the northern fringe of the Milky Way, and several spurs of starlight extend into the constellation at right angles to the galaxy's plane. The brightest spur appears as an 8° by 2° wisp that terminates in the center of the square of bright stars that forms the house's base.

Directly south of Cepheus and buried in the bright band of the Milky Way lies the constellation Lacerta the Lizard. Its smattering of modest stars forms a zigzag pattern that proves difficult to trace. The constellation's brightest star, 4th-magnitude Alpha Lacertae, is a bluish gem located 100 light-years from Earth.

Our telescopic tour begins with the open cluster **NGC 6939**. You can find it in the southwestern corner of Cepheus, where it forms an equilateral triangle with 3rd-magnitude Eta (η) and 4th-magnitude Theta (θ) Cephei. In an 8x50mm finderscope, NGC 6939 stands out nicely against the faint Milky Way background. It resolves well in a modest telescope, showing 60 stars between magnitude 11 and 13 in an area 5' across. Look for a prominent clump of five stars just west of the cluster's center.

Pan 5.5° north along the western edge of Cepheus and you'll come upon the Seyfert galaxy **NGC 6951**. In the past couple of years, two supernovae have been observed in this galaxy. Astronomers used the light output of the more recent one to refine their distance estimate to 110 million light-years. Seen across such a great distance, detail is fleeting. A 13-inch telescope shows NGC 6951 as a faint haze measuring 2.5' by 1' having a sharply concentrated core. Look for a 12th-magnitude star superposed on the galaxy's western edge.

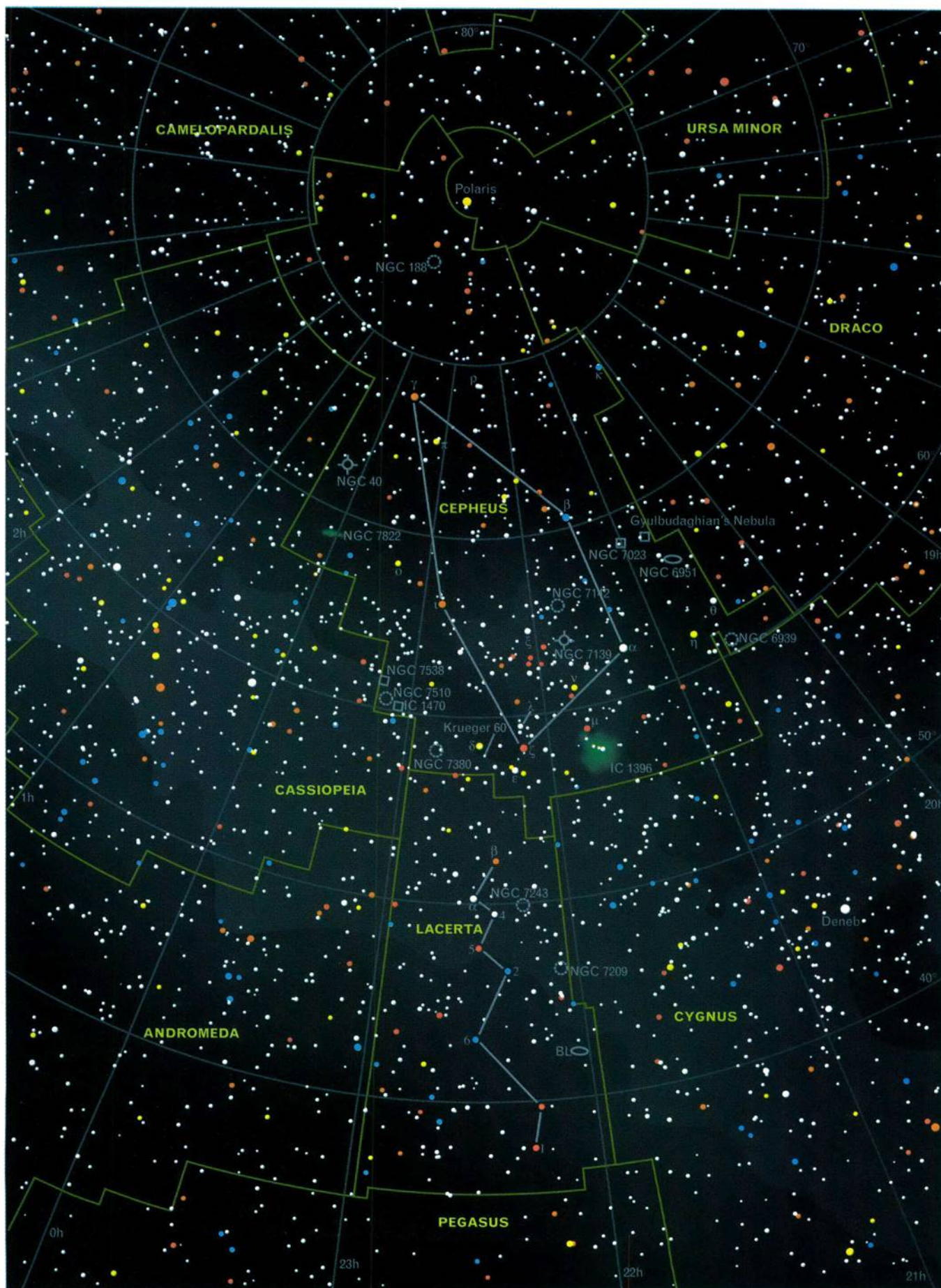
Head 3° to the northeast and you'll come to the photogenic reflection nebula **NGC 7023**. The nebula consists of countless dust grains, each only a few thousandths of a micrometer across, that reflect the light of a 7th-magnitude star at the nebula's center. In a 10-inch telescope, NGC 7023 appears as a uniformly bright, circular haze about 1' across surrounding this star, with a detached portion just to the south. Much larger telescopes begin to reveal a faint outer halo that brings the size to nearly 10'.

Another reflection nebula lies 1° west of NGC 7023, but observing it



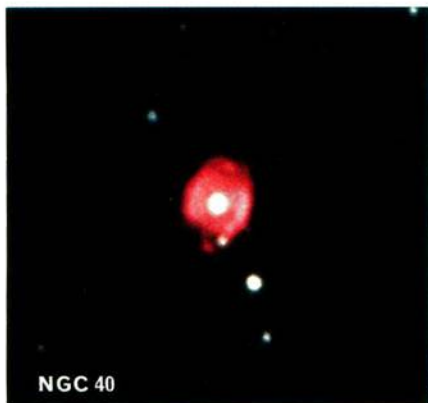
IC 1396

George Greaney



presents a much greater challenge. **Gyulbudhagian's Nebula** is a wedge-shaped object illuminated by the variable star PV Cephei. The nebula takes a cue from the star, varying in both brightness and apparent form. In repeated attempts at dark Arizona sites, I have consistently seen it in my 20-inch scope while it eludes a 10-inch. The larger telescope shows it only at magnifications above 150x, appearing as a very dim wedge near an asterism that looks like the constellation Crux.

Along the southern edge of Cepheus lies the ruddy 4th-magnitude star Mu (μ) Cephei. Dubbed the Garnet Star by William Herschel, it ranks among the reddest stars visible to the naked eye. It also serves as a guide to our next target. Mu marks the northern edge of the giant emission nebula **IC 1396**, which despite a distance of some 2,600 light-years spans more than 2°. Without the aid of a nebula filter, IC 1296 provides a challenge for small telescopes. It appears as a circular mist crossed by many dark lanes — a particularly prominent one points from the northwestern edge toward the center.



At the nebula's heart you'll find the naked-eye open cluster Trumpler 37, which contains 60 stars shining between magnitude 10 and 12 in an area 1° across. At higher magnification, the cluster's center resolves into a 6th-magnitude star with two 8th-magnitude companions. Ultraviolet radiation pours from these hot stars, ionizing the hydrogen gas that makes up most of the nebula and causing it to glow. Only about 3 million years old, Trumpler 37 ranks among the youngest open clusters known, and the central triple star system bears some similarity to the Trapezium in the Orion Nebula.

Moving southward into Lacerta, near that constellation's border with Cygnus, we come across an object whose nature remained hidden for decades. Although **BL Lacertae** carries the designation of a variable star, in the 1970s astronomers discovered it to be the brilliant core of a distant elliptical galaxy. In a backyard telescope, BL Lac appears only as a star, whose light varies between magnitude 14 and 16.

Pan about 3° west of the 5th-magnitude star 2 Lacertae to find the nice open cluster **NGC 7209**. It lies 3,500 light-years from Earth, embedded in a rich star field that makes its edge difficult to define. The cluster contains about 100 stars in an area 25' across, and shows up best at magnifications below 100x. The enigmatic star system SS Lacertae provides NGC 7209's main claim to fame. Until the late 1930s, the system appeared to be a normal eclipsing binary that varied regularly between magnitude 10.1 and 10.5. However, by the 1940s, the variations had ceased. Astronomers suspect that a third star in the system has altered the orientation of the system's orbit so that the eclipses no longer occur.

Deep-Sky Objects in Cepheus and Lacerta

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
NGC 7822	0h03.6m	68°37'	—	65' by 20'	BN	
NGC 40	0h13.0m	72°32'	12.4	37"	PN	
NGC 188	0h44.0m	85°20'	8.1	13'	OC	
NGC 6939	20h31.4m	60°38'	7.8	7'	OC	
NGC 6951	20h37.2m	66°06'	10.7	3.7' by 3.3'	Gal	SAB(rs)bc
Gyulbudaghian's Nebula	20h45.9m	67°58'	—	30"	BN	lit by PV Cephei
NGC 7023	21h00.5m	68°10'	—	10' by 8'	BN	
IC 1396	21h39.1m	57°30'	—	170' by 140'	BN	
Mu Cephei	21h43.5m	58°47'	3.4–5.1	730 days	Var	Garnet Star
NGC 7139	21h45.9m	63°49'	13.3	78"	PN	
NGC 7142	21h45.9m	65°48'	9.3	4.3'	OC	
BL Lacertae	22h02.7m	42°17'	14–16	—	Gal	Variable core
NGC 7209	22h05.2m	46°30'	7.7	25'	OC	
NGC 7243	22h15.3m	49°53'	6.4	21'	OC	
Krueger 60	22h28.1m	57°42'	9.8/11.2	3"	Dbl	
NGC 7380	22h47.0m	58°06'	7.2	20'	OC	
IC 1470	23h05.2m	60°15'	—	1.2' by 0.8'	BN	
NGC 7510	23h11.1m	60°34'	7.9	4'	OC	
NGC 7538	23h13.5m	61°31'	—	9' by 6'	BN	

Object: Designation in Messier, NGC, or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates.

Mag.: Visual magnitude. **Size/Sep./Per.:** Size in arcminutes or arcseconds; separation in arcseconds; period in days. **Notes:** Hubble type for galaxies.

The King

*"While Perseus entertain'd with this report/His father Cepheus, and the list'ning court/Within the palace walls was heard aloud/
The roaring noise of some unruly crowd." Metamorphoses, Ovid (43 B.C.–A.D. 17)*

When most of us think of kings, we envision glorious castles, ostentatious ceremonies, and vast wealth. In other words, everything is played out on a grand scale.

So imagine the initial surprise when you're learning the sky and go in search of the celestial king. Although Cepheus certainly holds a prominent place in Greek mythology, the stellar attributes of his constellation leave a lot to be desired. You can even "connect the dots" with the brightest stars, but the house you get looks more like simple suburbia than grand castle.

Surely, then, other cultures didn't elevate this region to royal status. Wrong again. Ever since the constellations were invented, people have seen a king in this area.



The Chinese called it the Secret Throne of the Five Emperors, and Arab astronomers dubbed him *al-Multafab*, the Blazing One. Perhaps the reason dates to the time 20,000 years ago when the north celestial pole lay within its confines. Every skywatcher would recognize the importance of that distinction.

For those with a modern bent, a more interesting royal connection exists. An Englishman of noble birth by the name of John Goodricke made

a landmark discovery in Cepheus. Despite being deaf and mute — and so frail he didn't survive past the age of 22 — in 1784 Goodricke used his keen vision to detect variations in Delta Cephei, ushering in a revolution in how we measure the scale of the universe. — *Richard Talcott*

The other bright open cluster in Lacerta lies 2.5° west of Alpha Lacertae. **NGC 7243** also suffers from the contamination of a rich star field, but it's a binocular object because its stars shine brighter than those of NGC 7209. An 8-inch telescope shows about 50 members scattered loosely across a diameter of 15'. The brightest star glows at 8th magnitude and appears centered in the cluster.

Our next target takes us back to Cepheus, inside that constellation's house asterism. The planetary nebula **NGC 7139** can be viewed in telescopes as small as 8 inches. The ghostly disk — formed when a sunlike star gently ejected its outer layers as it neared the end of its life — measures about 1' across and appears circular with a diffuse edge. A nebula filter will help you spot it. The central star glows dimly at magnitude 19, however, and cannot be seen in backyard scopes.

Now scan 2° north to find the open cluster **NGC 7142**, which ranks among the 25 oldest such objects in the Milky Way Galaxy. Seen across a distance of 6,000 light-years, the cluster's brightest stars glow only at 12th magnitude. Still, it's a pretty cluster that appears well detached from its surroundings. In a 10-inch telescope, it shows 35 stars in an area 5' across against a background glow of fainter stars. These fainter members raise the star count to about 60 in large scopes.

With a lower magnification and a wider field of view, you can see the cluster paired with the bright reflection nebula NGC 7133, which lies half a degree to the northwest.

Next move the telescope to Delta (δ) Cephei, the famous variable star that gave its name to an entire class of pulsating variables that plays a key role in determining distances throughout the universe. Then pan 43' south to find the pretty binary star **Krueger 60**. With a period of only 45 years, it's easy to see the position angle of the components change over just a few years' time. Although the two stars orbit each other at about the same distance as that which separates the sun and Saturn, they appear a generous 3" apart because the system lies only 13 light-years from Earth. The deep orange color of both components

makes Krueger 60 a very attractive target in a 6-inch or larger telescope at high magnification.

Scan 2.5° east of Delta Cephei and you'll find the open cluster **NGC 7380**. Visible as a faint haze in 10x50 binoculars, a medium-sized telescope shows about 30 stars, most glowing at 9th or 10th magnitude, scattered across a 10' field. Just as interesting is the surrounding emission nebula Sharpless 2–142. It appears as a mottled haze about half a degree long and elongated north to south. Use a nebula filter and about 50x for the best view. Both the nebula and cluster reside approximately 10,000 light-years from Earth.

Another emission nebula lies about 3° to the northeast. **IC 1470** belongs to our galaxy's Perseus spiral arm, located about 11,000 light-years away. With a large telescope operating at 200x, IC 1470 appears as a bright object half an arcminute across with a much fainter extension to the southeast. Look for a tight pair of 11th-magnitude stars 2' to the west.

A fine open cluster for any size telescope lies less than 1° to the east-northeast. **NGC 7510** shows a triangular arrangement of 25 stars, most between magnitude 10 and 12. The tiny object, only 2' on a side, stands out nicely against the rich surrounding star fields. Two parallel rows of the cluster's brightest stars dominate NGC 7510.



Jack Newton



NGC 7380

Michael Stecker

Pan another degree north and you'll land on **NGC 7538**, an emission nebula that belongs to a system of giant molecular clouds known as the Cassiopeia complex. In a 13-inch telescope, NGC 7538 appears as a faint mist enveloping two 11th-magnitude stars, which are separated by 30". The nebula extends about 9' by 6', but only the brightest region, located on the southwestern side and measuring 3' across, can be seen easily.

The emission nebula **NGC 7822** lies in the northern reaches of Cepheus. Unfortunately, its dim glow doesn't provide much visual appeal. However, with patience, a dark sky, and a 13-inch or larger scope, you can trace a milky haze 10' wide and several times as long across the rich star fields. If you have success with NGC 7822, it's worth going after Cederblad 214, a similarly faint nebula located 1.5° to the south.

Now head 4° north of NGC 7822 to one of the sky's finest planetary nebulae. **NGC 40** offers a superb sight in any telescope. Its high surface brightness allows you to pump up the magnification as far as the seeing conditions permit. A small telescope



NGC 6951

James R. Foster

readily shows the oval disk, which spans about 40" by 30", and a bright central star. Stepping up to larger apertures, the disk shows a thin, bright strip on both the eastern and western edge. The western strip glows brighter and curves off the disk on a tangent much like a galaxy's spiral arm. The planetary's interior appears quite mottled in periods of good seeing. The central star blazes at magnitude 10.6 but remains one of the coolest central stars.

Our tour concludes with one of the sky's most northerly deep-sky objects. The ancient open cluster **NGC 188** lies

4° from the 2nd-magnitude pole star, Polaris. An 8-inch telescope provides a pleasing view. At 100x, about 50 stars, 13th magnitude and fainter, crowd into an area 10' across. In a 17-inch scope, the star count doubles as dozens of fainter stars come into view. Dark lanes seem to run through the cluster stars, adding to the visual appeal.

Astronomers estimate that NGC 188 formed roughly 7 billion years ago, making it one of the oldest open clusters known. It certainly ranks among the oldest clusters located in the galaxy's disk. It owes its longevity to an orbit about the center of the galaxy whose closest point remains beyond 30,000 light-years. Researchers know that tidal effects prove fatal to the integrity of a star cluster that passes through the inner disk. That's why the big, bright star clusters located near Earth, like the Pleiades and Hyades, will eventually disperse. **A**

Tom Polakis is an aerospace engineer living in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.

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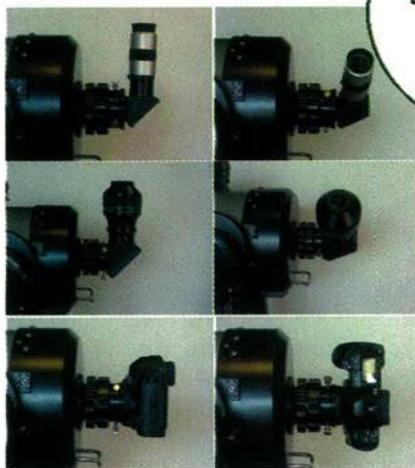
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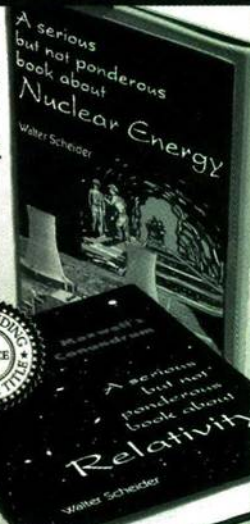


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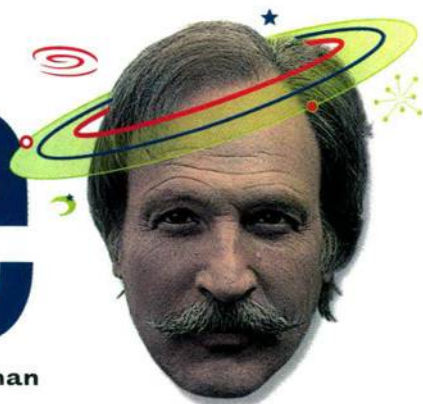
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■ strange Universe

by Bob Berman



Do Black Holes Exist?

Countless magazine articles and television science shows have described the violent scenario that produces a black hole. A heavy geriatric star collapses; as it shrinks, its surface gravity quickly rises to force it ever smaller. The implosion shrinks the unfortunate sun like a leaky balloon, until the velocity needed to escape its surface exceeds the speed of light and wham — it blinks out. If light can't escape, neither can anything else. The runaway collapse continues until the star achieves infinite density and occupies no space at all. It has become a singularity, and is surrounded by an "event horizon" — an invisible shell just a few miles away, a spherical zone where anything falling inward must vanish without hope of escape. As an incompetent astronaut who came too close, you wouldn't know that you'd crossed the horizon except that your phone calls wouldn't be returned. Then quite abruptly you'd be yanked violently downward and torn into dog food. Not a good day at the office.

We've all heard a description of this potential event. But it's probably never happened — and never will.

Jump back a moment to Einstein, who proved that time and distance can twist and change. Travel fast or hang out in strong gravitational fields and your time runs slower. And it's true: Fast-orbiting astronauts on the International Space Station have slower running clocks than those on the ground. Conversely, Apollo astronauts on the moon grew old faster because they were in weaker gravity than their stay-at-home friends. This didn't earn them early retirement benefits, but their speed-up was real enough to be measurable.

Or take the case of muons, particles created when cosmic rays collide with atoms of air. Muons live for just two millionths of a second, which even at their near-light velocity lets them travel only a half mile before they vanish. So they shouldn't live long enough to reach Earth's surface far below.

Yet they do. Muons pass through your body all the time and they're not totally harmless. Occasionally one will strike the wrong bit of genetic material in a cell nucleus and cause one of the "spontaneous" cancers that have always haunted our species. Done in by a muon. Another bad day.

Muons make it all the way to the ground because their time is slowed by their high speed, delaying their metamorphosis into harmless electrons. Or at least, that's what we observe. From a muon's perspective, things are different: time passes normally and it is length and distance that is

compressed. To a muon, Earth's atmosphere is just a few dozen yards thick, slim enough to penetrate in those few microseconds. Whose perspective is right and whose is wrong? That's Einstein's point: Both views are valid. Neither our sense of time and distance nor the muon's is absolute.

Okay, back to black holes. From the perspective of the collapsing star's atoms, there's no problem being yanked down to form a singularity of infinite density. (Well, maybe there is. Some relativity experts like Tarun Biswas of the State University of New York insist that relativity doesn't take into account factors like the "strong force" that would become increasingly important as material approached the singularity stage. They argue that since infinite density and zero volume are meaningless anyway, it's not less meaningless to suppose that some process like the strong force halts a star's collapse and prevents a singularity from forming).

Even if singularities can develop, from our perspective and the timeframe of everything outside the black hole — meaning, the entire universe — the collapsing material's time freezes so thoroughly that it takes infinitely long to crumple into a singularity and produce the accompanying event horizon. An infinite amount of time has not yet elapsed, and it never will.

So black holes cannot form, period. The only ones that might exist would have had to be already present at the Big Bang, before time began. The common garden variety, collapsing-massive-star scenarios so often repeated in print and on television simply cannot happen in our reality, our universe, our timeframe.

Recently I debated this point with one of the country's top astronomers; let's call him Alan Phillips. It was at a convention and a crowd gathered, listening intently. Edited out is everything I said that doesn't make me seem like a genius.

Al: "You're going to tell readers that black holes don't exist? You shouldn't do that! Just because we can't see them doesn't mean they're not there. Lots of things exist that can't be seen, like extrasolar planets."

Me: "But those are real and better instruments may someday see them. Black holes will never be detected because it takes infinitely long for them to form, and infinite time has not yet passed since the universe's birth."

Al: "It's a matter of perspective. Muons see time and distance differently from us, yet their viewpoint is just as valid

as ours. Similarly, a singularity forms in its own timeframe even if it doesn't happen in ours."

Me: "There's a difference. Muons exist from all perspectives. Only their paths through time or distance are seen differently by them and by us. But black holes never form at all in our timeframe."

Al: "But they do form."

Me: "Really? Then give me a possible date in our reality in which a supposed black hole like Cygnus X-1 might have arisen. Yesterday? A billion years ago? Day two after the Big Bang? Tell me when such a thing could have happened!"

Later I thought of this: Science and human experience always describe things from Earth's time frame. No textbook would claim that our atmosphere is just a few yards thick simply because a muon sees it that way. Why, then, are we supposed to negate our reality and that of the whole universe in favor of the perspective of an infalling atom in a collapsing star? At the very least, our timeframe (in which singularities and event horizons never form) should be accorded equal — if not exclusive — validity, but that's not what happens in today's stories about black holes.

Al: "Okay, I'll agree that singularities and event horizons have never formed and never will. But people would be confused if you said that black holes don't exist. How about instead redefining a black hole? Call it a thin membrane of dense material that hovers just above an event horizon."

Me: "You mean, above where an event horizon would form in the imaginary infinite future? Fine!" And we shook hands.

Observationally, this changes nothing. We'll still observe the screams of flickering x rays from trapped infalling material. This is more a philosophical or visual reappraisal. Instead of picturing sinister vacuum cleaners, think of black holes as floating trash compactors — bizarre spherical membranes of dense material that hover in space as time grinds to a halt.

Either way, it's an unforgiving place where the galaxy's garbage and riff raff are inexpensively removed. What more can we want? **A**

Bob Berman regularly writes Strange Universe for Astronomy.



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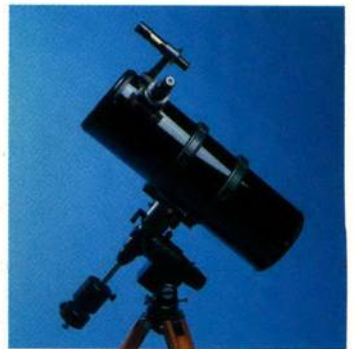
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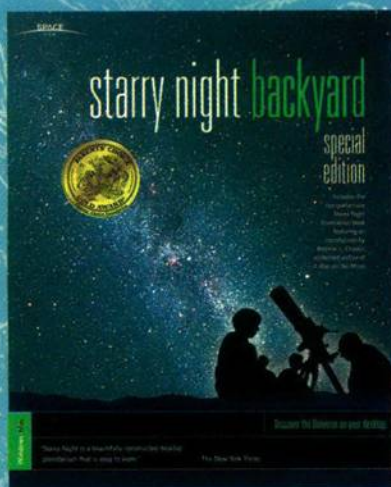
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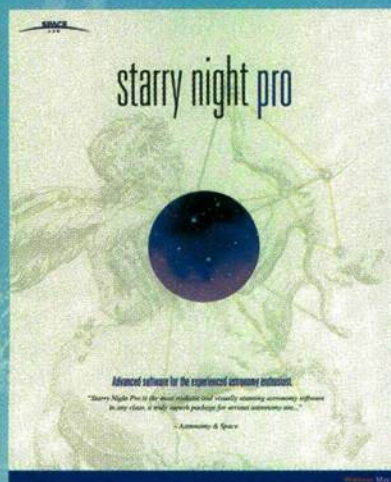


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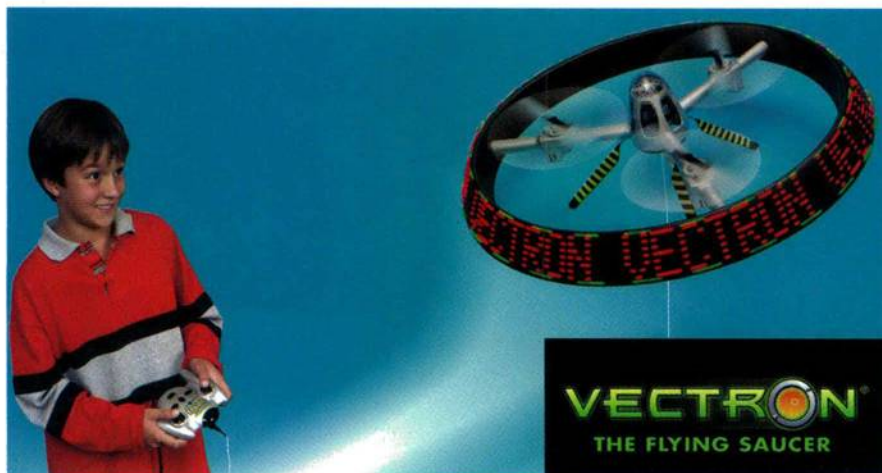
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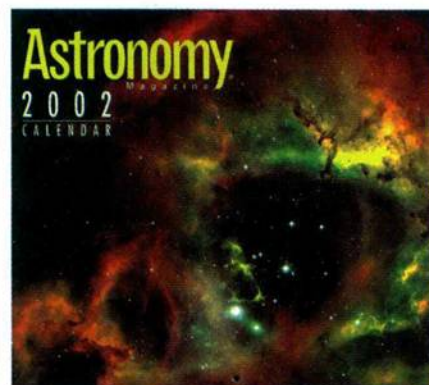
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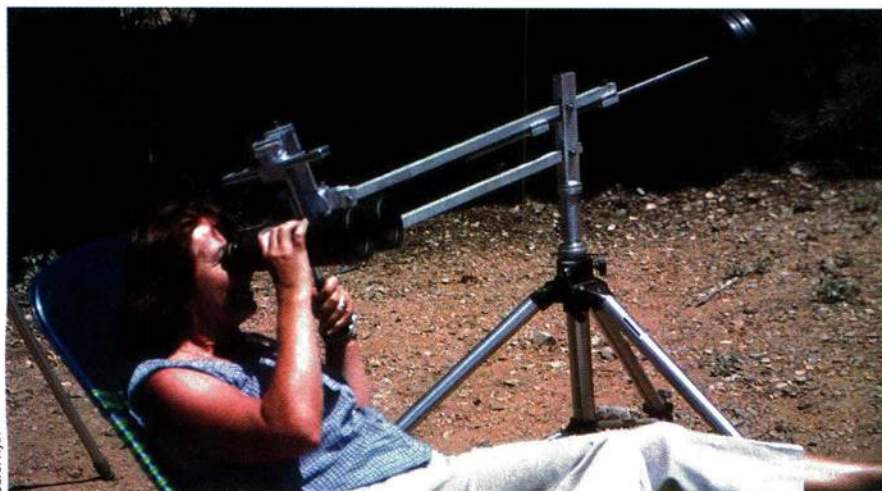


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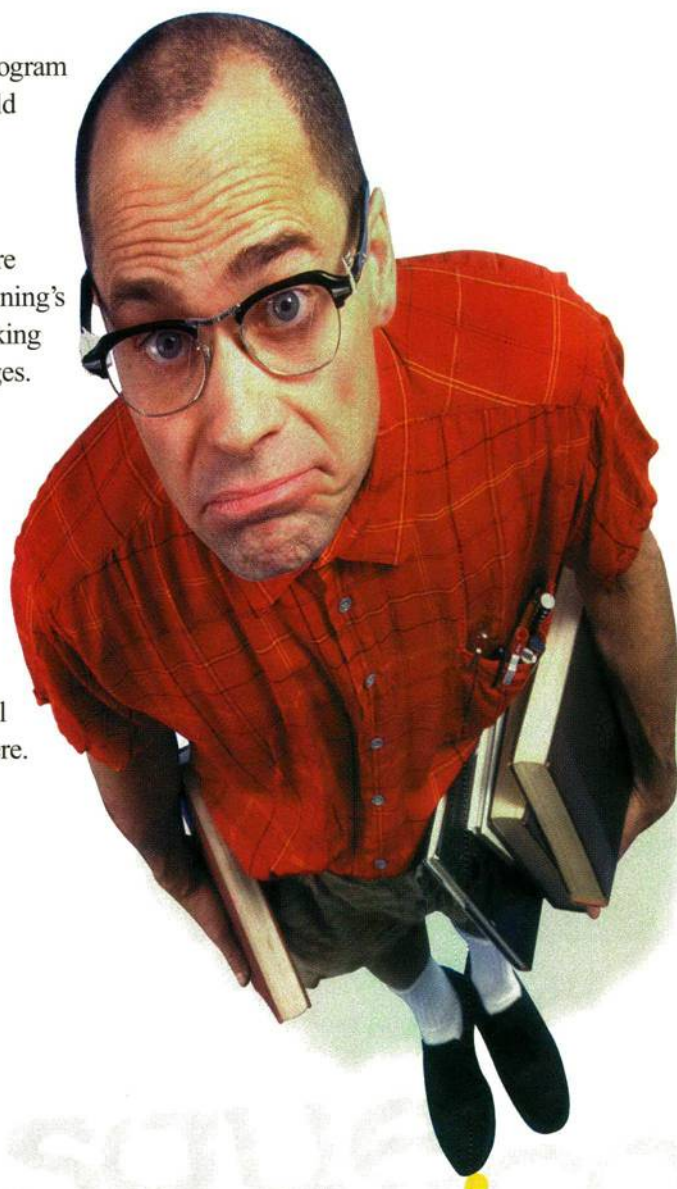
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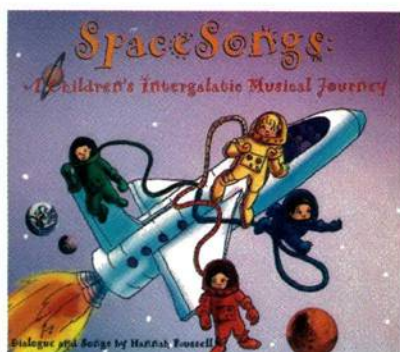


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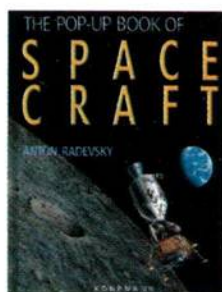
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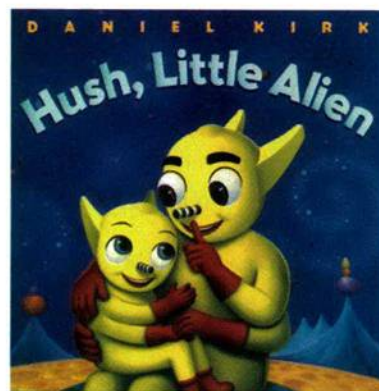
Anton Radevsky, 10 pages, Könnemann Publishing, Bulgaria, 2000; ISBN 3-8290-4864-5; hardcover, \$19.95.

► Although the age group for this

book is listed as four through eight, anyone with a sense of whimsy will think it's cool. The pop-up spacecraft, satellites, and extraterrestrial vehicles unfurl to provide readers with a paper model suspended above the pages. Various rockets "launch" from the book or hide peek-a-boo fuel tanks to give a better idea of their innards.

Sparse text sprinkled over backgrounds of Earth, Mars, or the moon contains a fair number of facts and

details geared toward an older audience. As author, illustrator, designer, and paper engineer, Radevsky shows his Eastern-European roots by emphasizing the Soviet space contributions whenever appropriate. That changes somewhat by the center spread, which enlarges to include an American lunar base complete with the lunar module, rover, and astronaut's footprints. I wish someone had given me a book like this when I was a kid — but now I'll buy it for myself. — Carol Ryback, associate editor



Hush, Little Alien

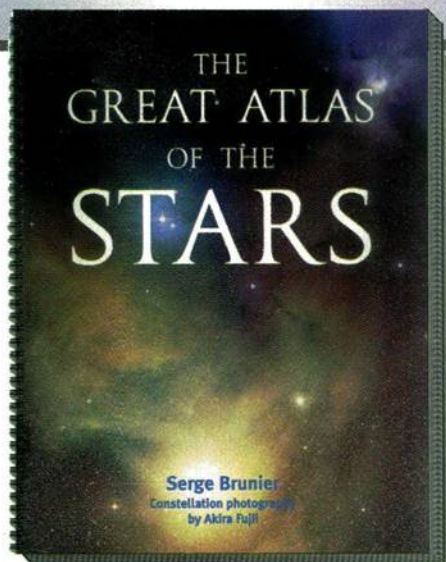
Daniel Kirk, 24 pages (board edition), Hyperion Books for Children, New York, 2001; ISBN 078680759-8; hardcover, \$6.99.

► In this bedtime story for preschoolers, a father alien retells the "Hush, Little Baby" song. Instead of mockingbirds and billy goats, Papa promises his offspring shooting stars and satellites and a trip to the Milky Way. Youngsters will love this brightly colored book and will beg to hear it over and over. — C. R.

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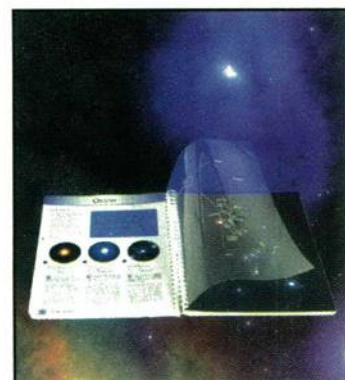


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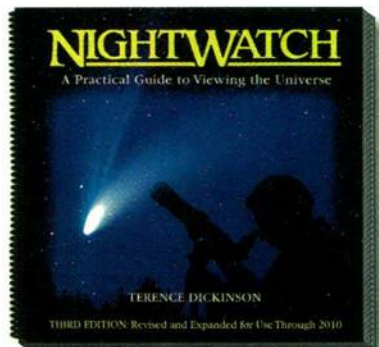
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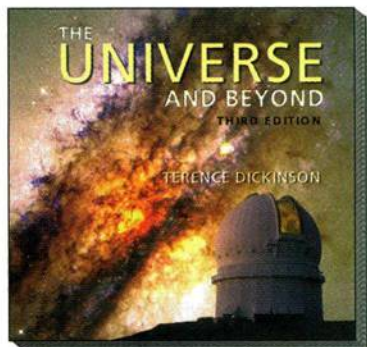


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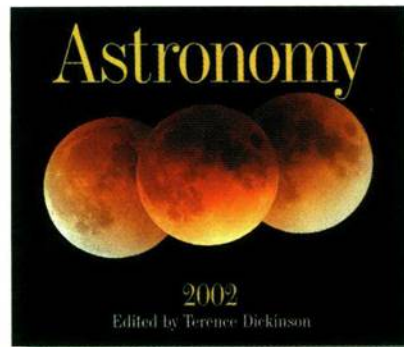
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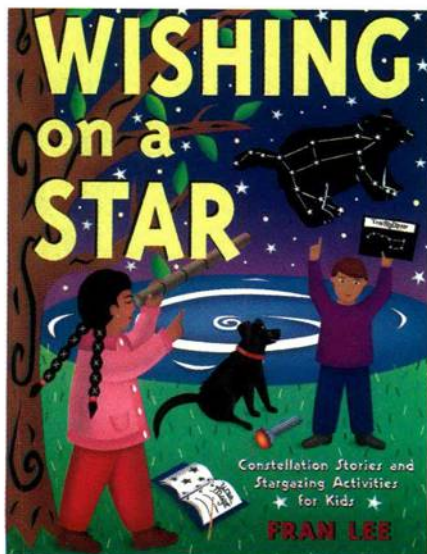
Robin Kerrod, Barron's Educational Series, Hauppauge, New York, 2000; ISBN 0-7641-7383-9; \$29.95.

▶ Robin Kerrod, a Fellow of Britain's Royal Astronomical Society, developed this basic kit to get you started in stargazing. It not only helps beginners identify constellations and locate specific stars, but also explains astronomical terms and celestial phenomena. This kit includes a planisphere (for 42° N) and a red flashlight, as well as bound star maps and guides. — C. R.

Wishing on a Star

Fran Lee, 62 pages, Gibbs Smith, Layton, Utah, 2001; ISBN 1-58685-029-6; paperback, \$9.95.

▶ Stories and drawings about the major constellations pique interest in the universe and night sky. With this astronomical activities book for ages six and above, children can make their

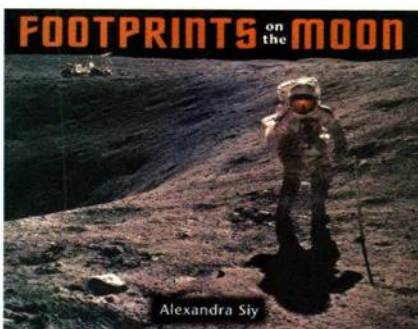


own glow-in-the-dark star maps or mobiles, put on a play that tells the story of Cygnus, or make a device to represent the twinkling stars. It's fun stuff that makes learning painless for kids of any age. — C. R.

Footprints on the Moon

Alexandra Siy, 32 pages, Charlesbridge Publishing, Watertown, Massachusetts, 2001; ISBN 1-57091-409-5, softcover, \$7.95.

▶ *Footprints on the Moon* gives a brief history of the beginning of human interest in astronomy and manned flight, then concentrates on the lunar landings. Many of the photos are already familiar icons, but a few offer a new perspective. One taken by Michael Collins shows Eagle, the first lunar module, as it rises from the moon's surface. Earth is in the background, and the caption sends chills up your spine as it reminds you that (except for himself) Collins captured all of humanity on film in one shot.



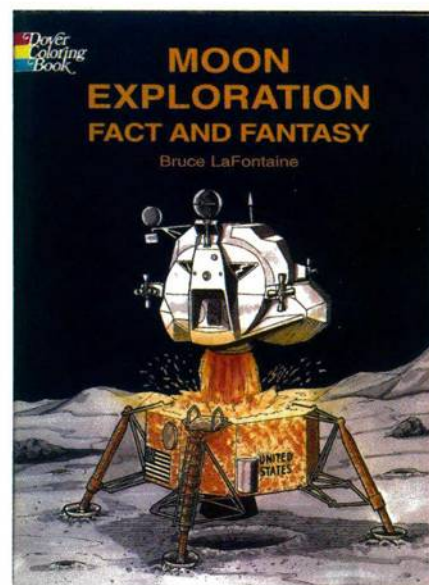
The book ends with futuristic drawings of proposed space expeditions. It's a good record for fans of the Apollo missions, and an easy history lesson for anyone under 30. — C. R.

Moon Exploration Fact and Fantasy

Bruce LaFontaine, 48 pages, Dover Publications, Mineola, New York, 2001; ISBN 0-486-41549-X; paperback, \$3.50.

▶ This coloring book traces the conquest of the moon with drawings of actual events as well as those pulled from myths and popular culture throughout the centuries.

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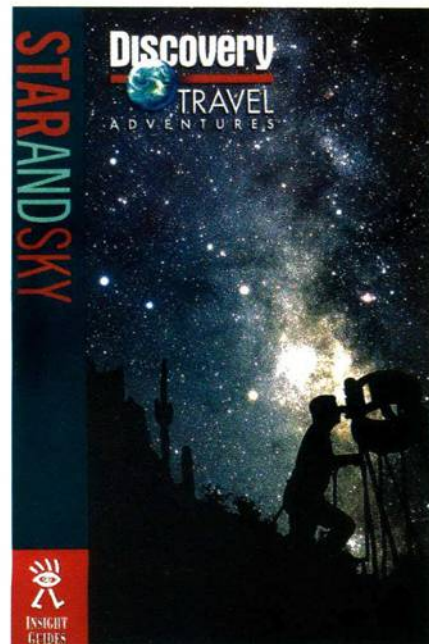


Star and Sky

Robert Burnham, Editor, 224 pages, Discovery Communications, Langenscheidt Publishing Group, Maseth, New York, 2000; ISBN 1-56331-926-8; softcover, \$19.95.

▶ *Star and Sky* aims at amateur astronomers whose vacation goal is to visit as many professional observatories, planetaria, or space museums as possible. Complete with addresses and hours, this travel guide invites you to see them all.

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stargaze wherever they happen to stop for the night.

Information on space camps and star parties, as well as a resource guide for further reading, rounds out this handy chapbook. — C. R.

Spinning Through Space Series

Raintree Steck-Vaughn Publishers, Austin, Texas; eight-book set: \$205.52; four-book set: \$102.76.

Comets and Asteroids

by Eva M. Hans, 32 pages, (2001), ISBN 0-7398-2742-1; hardcover, \$25.69.

Constellations

by Eva M. Hans, 32 pages, (2001), ISBN 0-7398-2743-X; hardcover, \$25.69.

Space Mysteries

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by Mike Goldsmith, 32 pages, (2001), ISBN 0-7398-2744-8; hardcover, \$25.69.

► These are the kind of science books that first-through-fourth graders just

eat up. Spark your child's interest and hook her early with this easy-to-read set. Coax further learning by consulting the glossary and sources listed for additional information. Before you know it, you'll have an astronomer on your hands. — C. R.

Spinning Through Space Series

Tim Furniss, 32 pages, (2001); Raintree Steck-Vaughn Publishers, Austin, Texas, hardcover, \$25.69 each.

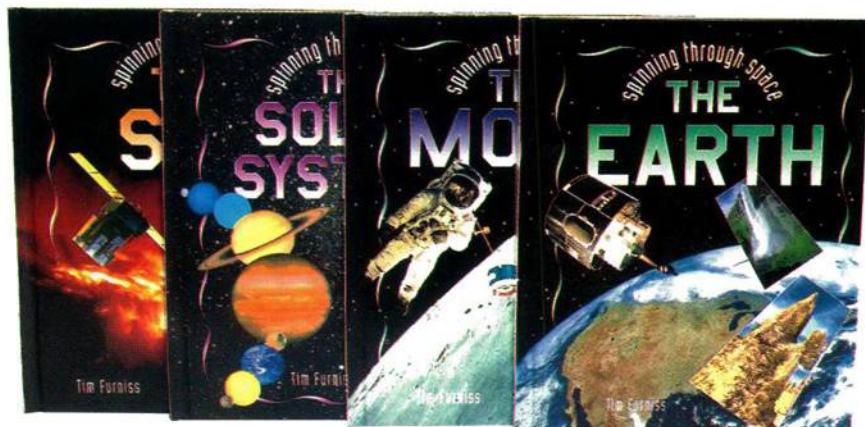
The Earth (ISBN 0-7398-2737-5).

The Moon (ISBN 0-7398-2738-3).

The Solar System (ISBN 0-7398-2740-5).

The Sun (ISBN 0-7398-2739-1).

► Packed with bright photos and plenty of basic astronomy facts, this introductory series of beginner's books will fascinate elementary students. While some of the information repeats from book to book, each is different enough to hold the interest of younger students. Every book includes a glossary and further reference sources; additionally, *The Sun* and *The Moon* contain tips for teachers. — C. R.



The Webweaver Picks

by Richard J. Bartlett

Screen Savers: What Lies Behind

On those all-too-frequent cloudy nights, we can only dream about the stars. That means it's time to get thee behind those dark clouds with a good screen saver.

For instance, the Sky Screen Saver by John Walker is the perfect program to run during



your PC's idle time. This neat little screen saver displays a "fisheye" view of the entire sky, complete with sun, moon, and planets, from wherever you may be on Earth.

Available free from <http://www.fourmilab.ch/skyscrsv/> for Windows 3.x, 95/98/2000 and NT, it comes as a single 190K zipped file. Once installed, you can customize it to suit your own star chart preferences.

John Walker offers another freebie as well — the Earth Screen Saver for Windows 95/98/2000 and NT. It displays the current view



of Earth from the sun, moon, Earth's night side, or any other point over Earth's surface. The resulting image is based upon a topographic map, so

no fluffy white clouds interfere with the view. Download the 658K file from <http://www.fourmilab.ch/earthscr/>.

Say you're waiting for the skies to clear and decide to go on-line with a faraway friend in Australia. But what time is it there? The Sun Clock screen saver from Map Maker Ltd. dis-

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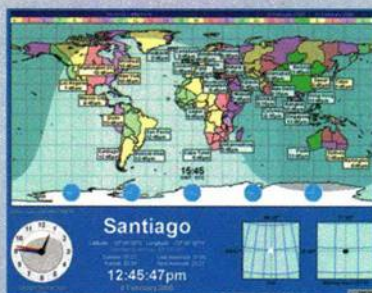
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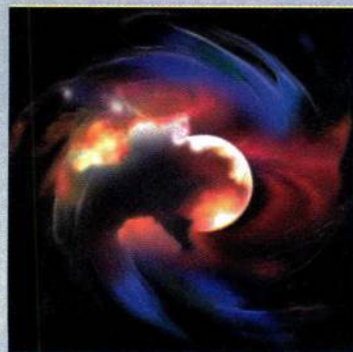
The Webweaver Picks (cont.)



plays a time-zone map of the world. It lists current times at major cities and indicates day and night across the globe. As a bonus for astronomers, it also displays the current Julian date, sun and moon rising and setting times, plus a graphic depicting the real-time status of the sun and moon. Available free from <http://www.map-maker.com/sunclock.htm>, it downloads as a 538K file for Windows 95/98 or 2000.

If you've ever dreamed of a flight of fancy among our nearest neighbors, try the Solar Saver from Shifthead Software. Imagine yourself as a kamikaze comet, swooping past the planets, hell-bent on a close encounter with the sun. Just when you think it's over and you're heading toward the stars, you find yourself pulling back for another roller coaster ride. Despite the simplistic renderings of each planet, there's an almost hypnotic appeal here. Download the Solar Saver from <http://www.shifthead.com/downloads/default.htm> as a self-extracting, 647K file for Windows 95/98 or 2000.

For those voyagers who like majestic worlds, check out Brian Smallwood's Europa screen Saver. It's opening pays homage to *2001: A Space Odyssey*, and places you on the surface of the enigmatic moon. Watch other moons, the sun, and Jupiter rise as meteors fall on a series of fantastic and imaginative vistas. High-quality graphics cause this screen saver to run slowly on older PCs; unlike the previous programs, this one is



shareware. The free demo contains limited scenes, and a "nag box" at the end of each cycle reminds you to register. The full version costs \$10, runs eight minutes longer, and includes an ice cavern sequence. Download the 877K demo for Windows 95/98 or 2000 from <http://www.firstinspired.com/spaceprime/space.htm>.

Trek across the universe with Lightspeed, a free, 2.8MB version for Windows 95/98 and 2000 from <http://www.starfield-screen-saver.com/>; there's a \$15 registration fee for accessing all the features. Many imaginative views include such classics as "warp speed" — as well as flybys of galaxies, globular clusters, and pixelated planets. Or take the helm yourself and steer your own course across the cosmic ocean. I found that despite having the necessary hardware, my laptop screen flickered quite badly with Lightspeed.

Similarly, Galaxies from Mathematically Beautiful Screen Savers takes you on a whirlwind tour of a virtual universe. However, although Galaxies and Lightspeed operate in a similar manner, Galaxies allows you to create your own universe by customizing the appearance and frequency of galaxies, nebulae, comets, and novae. As with Lightspeed, this screen saver is shareware but there are no restrictions on its functions pending payment. Registration costs \$10; download the 358K file from <http://www.mathsavers.com/galaxies.htm>.

The Distant Planets screen saver allows you to visit planets and see comets, double stars, moons, nebulae, and galaxies from the surface of more than 32,000 imaginary worlds. Although occasionally simplistic, the views are also surprisingly beautiful.

Distant Planets runs on Windows 95/98/NT/2000/ME and can be downloaded from

<http://www.geocities.com/SiliconValley/Way/9877/distantplanets.htm>. The tiny file size (52K) takes only a few seconds to download. Best of all, it's free.



Or, leave your mark in space with the StarMessage screen saver by Michael Ioannides. This program moves the stars to form the message of your choice. Add a graphical depiction of the current phase of the moon, other customizable features, and Michael's unique sense of humor, and you have a screen saver that's worth the five-minute download time. It's shareware, and costs \$10 to register, but you can try it for free at <http://users.spark.net.gr/~mediaw/starmsg/>.



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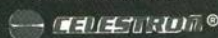
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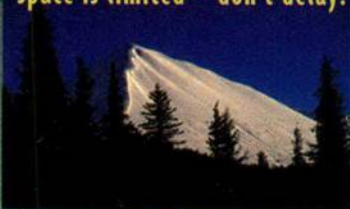
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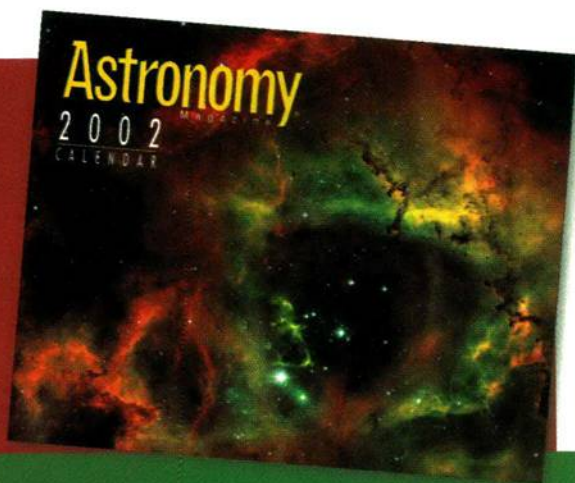
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Over the past four decades, lunar explorations, space probes, and powerful, ground-based telescopes have given us dazzling images of Earth, the planets and moons, distant galaxies, supernovae, and stellar nurseries. These pictures — a blend of art and science — have awed us with their beauty and reshaped our knowledge of the structure of the universe.

October 7, 2001 through January 13, 2002, the California Center for the Arts in Escondido, California, is running two concurrent exhibitions examining America's fascination with space travel and exploration and taking visitors on a journey from futuristic fantasy to modern-day realism. **"To the Moon and Beyond: Astronomers and Photographers Explore the Heavens"** presents more than 75 stunning photographs, ranging in date from the 1969 Apollo 10 mission to more recent images from ground-based observatories and orbiting spacecraft such as the Hubble Space Telescope, Mars Global Surveyor, Cassini-Huygens, Clementine, and Galileo. Highlights include spectacular works from artist Michael Light and astrophotographer David Malin. **"Blast Off! Space Toys and the American Imagination"** presents more than 100 spectacular examples of pop culture's most interesting representations of outer space — space toys. From Buck Rogers to the "Gang of Five" robots, this exhibit includes a rare collection of space helmets, ray guns, robots, comic books, and other artifacts that reflect America's early attraction to the world beyond.

For more information, call (760) 839-4120 or contact the Center's website at www.artcenter.org.

SMITHSONIAN EXHIBITION Explore the Universe

The Smithsonian Institution's National Air and Space Museum in Washington, D.C., is presenting a new, permanent exhibition covering the evolution of man's tools for searching the heavens — from the naked eye, to telescopes, photography, spectroscopy, and present-day use of digital media.



Hui Yang (University of Illinois) and NASA

Spectacular images from the Hubble Space Telescope will be featured at the California Center for the Arts exhibition, taking place through January 13.

Admission is free. For more information, contact (202) 357-2700; website, <http://www.nasm.si.edu/galleries/gal111/univ.htm>.

NOVEMBER 14

Silicon Valley Astronomy Lecture Series
Foothill College, Los Altos Hills, California. 7 P.M. Lynn Cominsky of Sonoma State University will speak on **"Exploding Stars, Blazing Galaxies, and Giant Black Holes: The Extreme Universe of Gamma-ray Astronomy."** Sponsored by NASA Ames Research Center, Foothill College Astronomy Program, the SETI Institute, and the Astronomical Society of the Pacific. For more information, call the series hotline at (650) 949-7888.

NOVEMBER 15-18

National Meeting of Brazilian Amateur Astronomers

Salvador, Bahia, Brazil. Sponsored by the Associacao dos Astronomos Amadores da Bahia. For more information, contact Wilton Carvalho; phone/fax, 55-71-367-0129; e-mail, wilton@e-net.com.br.

NOVEMBER 17

Shreveport Star Party

Ralph A. Worley Observatory, south of Shreveport, Louisiana. Contact Cran

Lucas, (318) 797-1524; e-mail, clucas@softdisk.com; website, <http://www.lsus.edu/nonprofit/sbas/>.

NOVEMBER 17-19

Astrofestival

Blindern, Oslo, Norway. Sponsored by the Norwegian Space Centre, the Research Council of Norway, and the University of Oslo. For more information, contact Knut Jorgen Roed Odegaard, Astrofestival 2001, P.O. Box 1029 Blindern, NO-0315 Oslo, Norway; telephone, 22-85-75-22; e-mail, knutjo@astro.uio.no; website, <http://www.astro.uio.no/ita/arranger/astfest01/astfest01.html>.

DECEMBER 1-JANUARY 12

Origins: Antarctica

The Exploratorium, San Francisco, California. Origins mixes live internet webcasts with interactive presentations. The Exploratorium will take the public on expeditions and field trips to laboratories throughout Antarctica. Using two-way video conferencing technologies, the Exploratorium will connect viewers online and visitors on the museum floor to scientists working in Antarctica.

The following locations will be witnessed: McMurdo Station; Cray Center, a laboratory for cosmic ray

influx studies and other research; Penguin Ranch sea ice camp; Mount Erebus Volcano Observatory; Dry Valleys/Lake Hoare and the Center for Astrophysical Research (CARA)/the South Pole, an ideal spot to study the origins of planets, stars, and the universe due to the lack of water vapor in the atmosphere, which makes the infrared spectrum of sky clearer and darker than any other spot on Earth. The South Pole station is home to three major telescope facilities — the Astronomical Submillimeter Telescope used to survey interstellar gas; the South Pole Infrared Explorer to observe distant galaxies, cool stars, and heavily obscured star-forming regions, and the Cosmic Background Radiation Anisotropy to help researchers test current theories of the origin of the universe.

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FEBRUARY 11-16

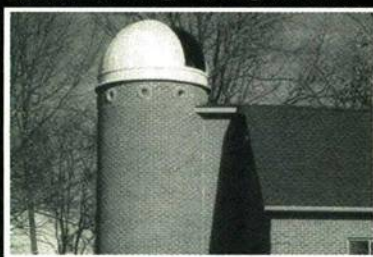
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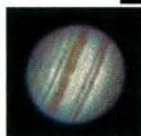
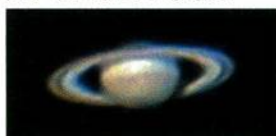
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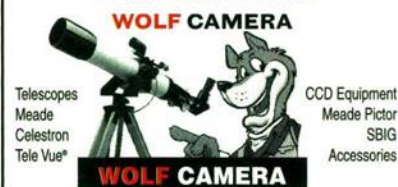


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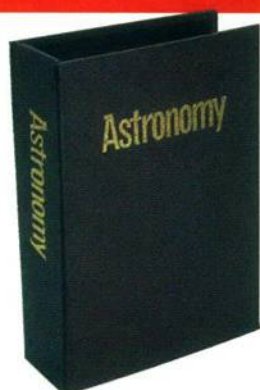
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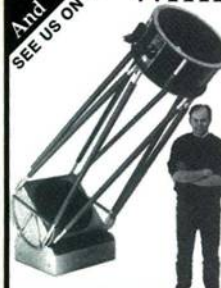
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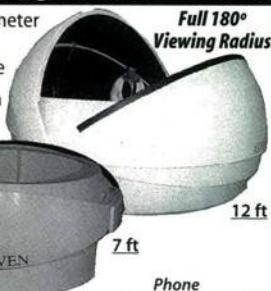
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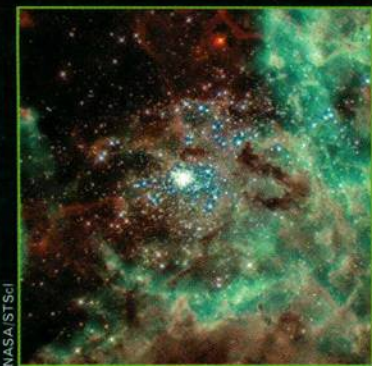
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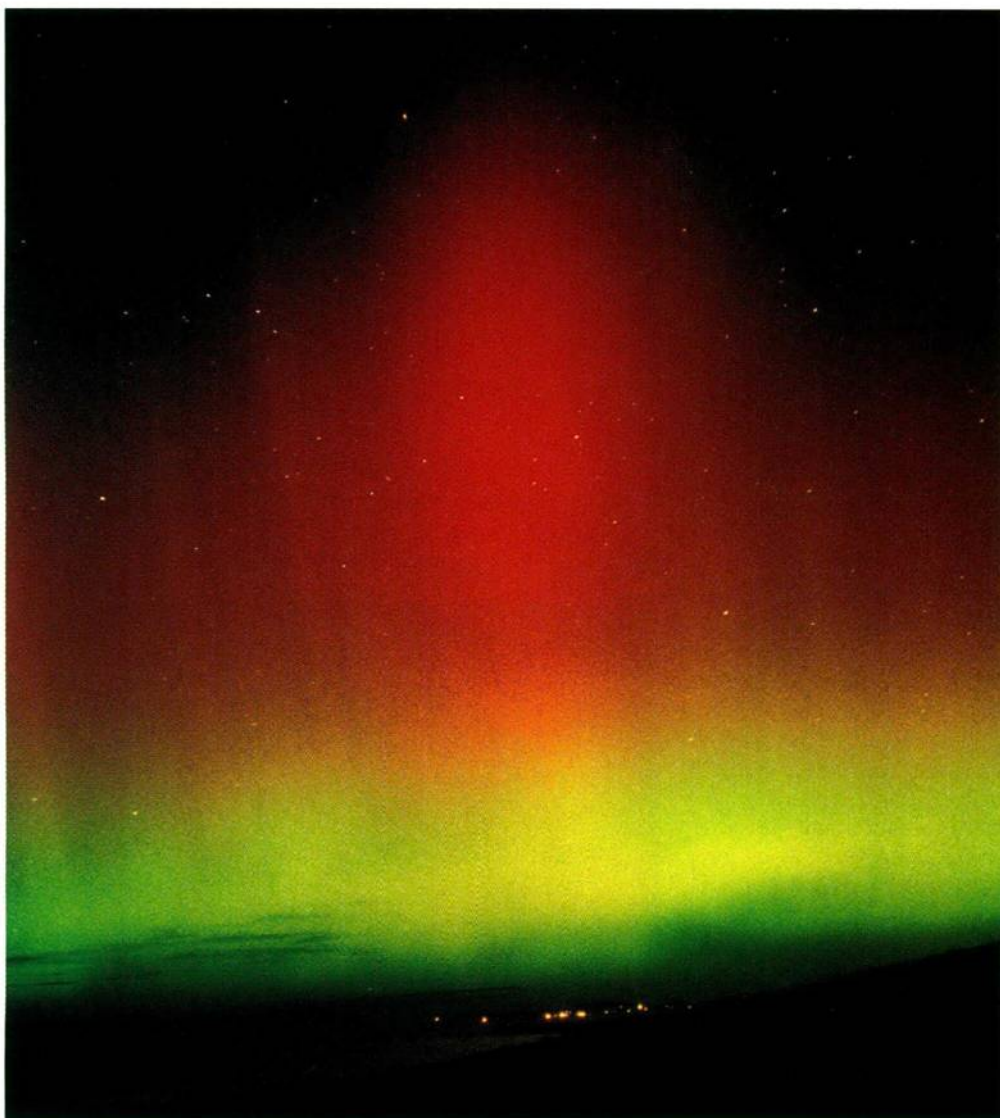
Impromptu Star Party

► Last spring I enjoyed one of the best viewing experiences of my life. It wasn't because of the objects that I observed, or how clear the sky happened to be that night. But I will always remember the night I was able to introduce the wonders of the universe to a special group of people.

My wife, daughter and I had only recently moved into the new home we had built in a small but quaint subdivision. Situated in an ideal location, it provides for rather good dark-sky observing. While this wasn't the first time I had observed from my home, what happened as the night progressed was something truly unique.

After setting up my scope at dark, I began observing as I had so many times from my driveway. About a half hour into my session, I noticed two of my neighbors from a couple of houses down walking by very slowly. Neither of us said anything. A little while later the same neighbors came back in the opposite direction, moving just as slowly. I glanced up and said hello. As they still lingered, I asked them if they would like to take a look. Sure enough, they came over eagerly.

Saturn and Jupiter were well-placed for viewing, so I put Saturn into the eyepiece; it always makes for a great first impression. My neighbors "oohed" and "ahhed" as they looked



New Zealand Auroral Display

DAVID ARMSTRONG

(200 ISO film, taken from South Island, New Zealand, on June 18, 2001)



Comet Petriew (P/2001 Q2)

JACK NEWTON

(16-inch SCT at f/10, Finger Lakes Dream Machine CCD camera, taken August 24, 2001)

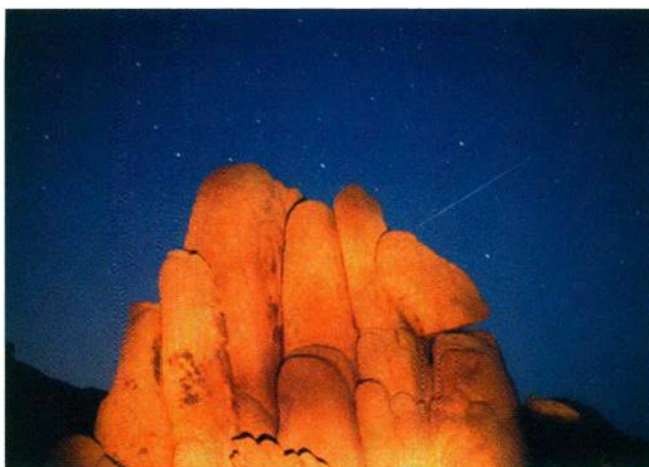


through the eyepiece, not believing how much detail they could see. After a few minutes I pointed the telescope at Jupiter, and again they gasped. I was enjoying showing them other objects when I noticed that our neighbors from across the street were walking over with several friends. They had seen us from their window and were curious as to what we were looking at. Again, I slewed back to Jupiter and Saturn.

More “oohs” and “ahhs” followed as each person got their turn at the eyepiece. Soon, the next-door neighbors and their in-laws were joining our group. It wasn't long before there must have been 15 to 20 people in the driveway, all excitedly chatting and waiting in line to view the next object. Someone blurted out that we were having a star party. I smiled to myself, as everyone present probably had no idea that is exactly what we amateurs call a gathering like this.

The party continued to grow. The highlight of the entire night was when the pizza guy on a delivery stopped, parked his car on the street, and asked if he could take a look. To see him standing at the telescope wearing the well-known uniform and hat was priceless, not to mention the fact that someone's pizza was getting cold and he couldn't have cared less. Our group spent the next several hours viewing object after object. People talked amongst themselves and asked all sorts of questions.

Our impromptu star party brought our neighborhood a little closer together. Now neighbors regularly stop by when they see me observing. Even the



Perseid Meteor Over “Giant Hand” Rock Formation

WALLY PACHOLKA

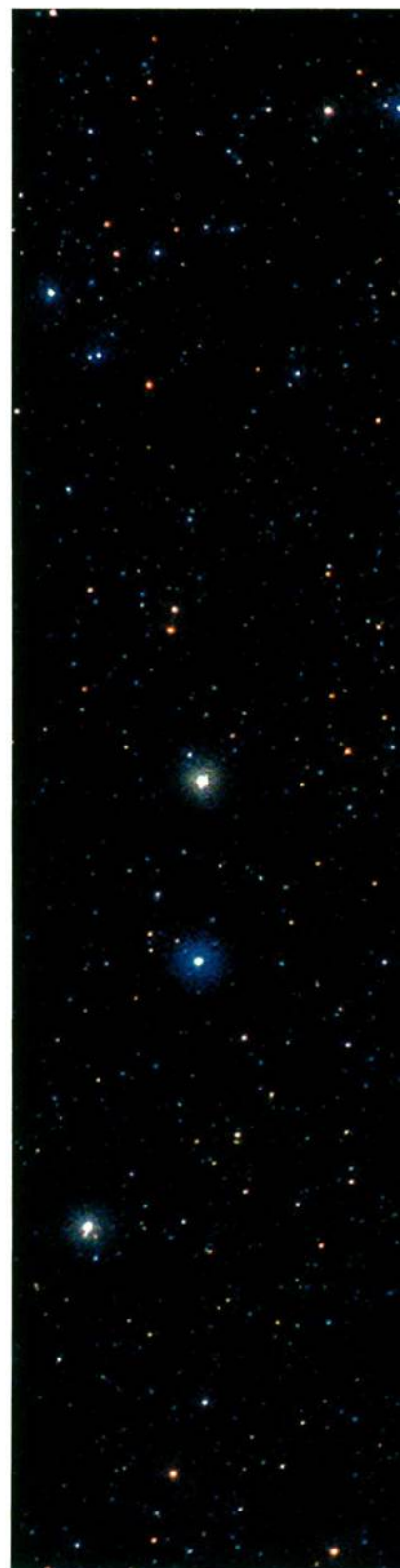
(50mm lens at f/1.4, Fuji 800 film, 30-second exposure, August 12, 2001)

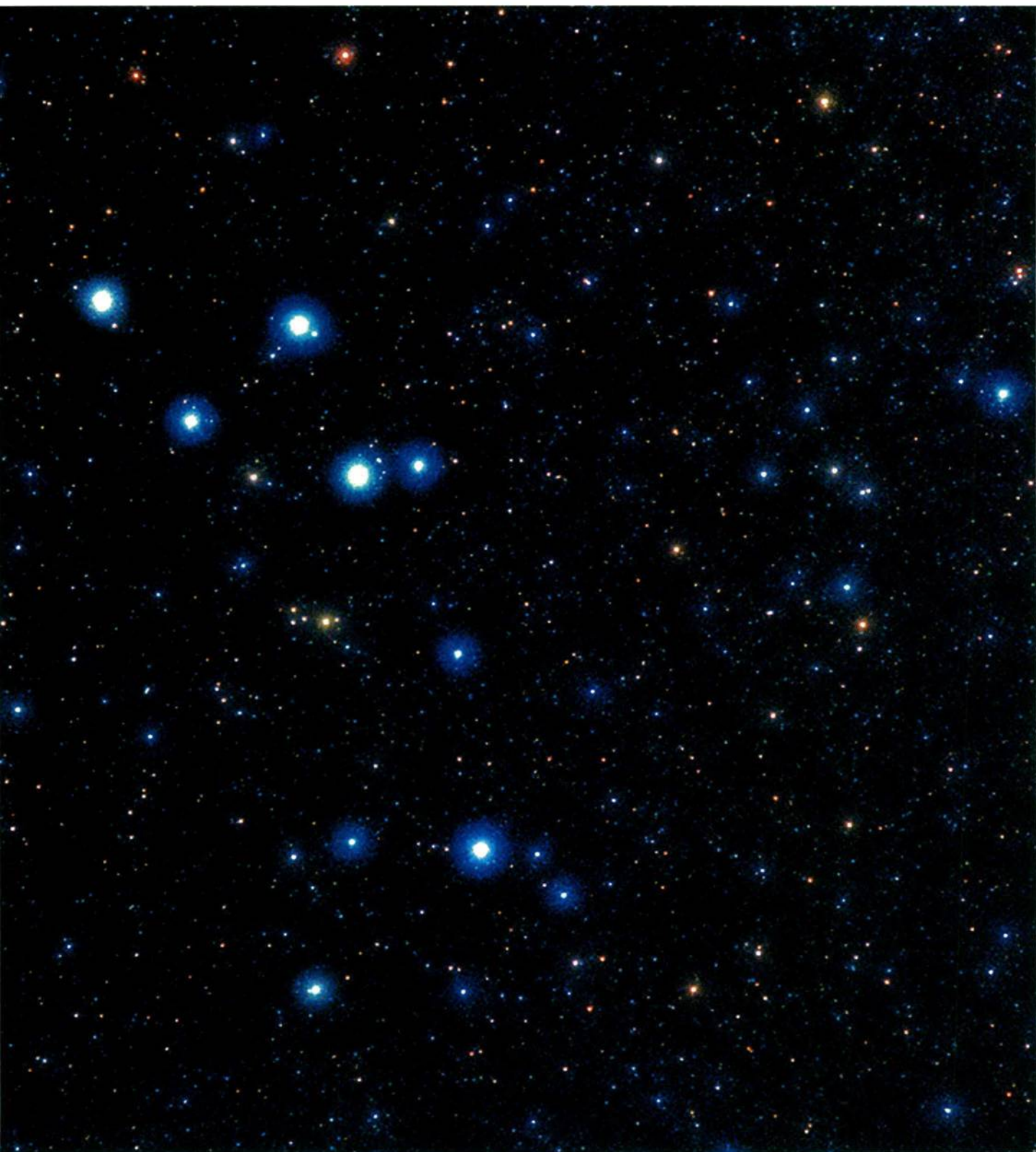


Moon and Venus Setting Over Lake Murray, California

JERRY SCHAD

(300mm lens at f/2.8, Ektachrome 200 film, taken December 29, 2000)





Delphinus Region

GIANNI TUMINO AND MELANIA PLUCHINOTTA

(105mm lens at f/4, Kodak E-200 film, 20-minute exposure)



pizza guy has stopped again. But the first night I was able to open up the universe to a few more people will always remain a special memory. **A**

Paul Atkinson enjoys observing from his home in Fort Meyers, Florida.

Share Your Stories

Send your 500- to 800-word reports describing your observing experiences to:

Hot Shots, *Astronomy* magazine, P.O. Box 1612, Waukesha, WI 53187-1612

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hotshots@astronomy.com



The Bubble Nebula (NGC 7635)

JEFF RZEPKA

(10-inch SCT at f/10, ST8E camera,)



Star Trails Over Astrohaven Domes, New Mexico

JOHN NEMY AND CAROL LEGATE

(28mm lens at f/3.5, Kodak Slide 200 ISO film, 3-hour exposure)





North America Nebula (NGC 7000)

THOMAS WILLIAMSON

(50mm lens at f/2.5, Fuji 800 film, 8-minute exposure)



Galaxy NGC 772

CHRIS SCHUR

(12.5-inch reflector, SBIG ST7E CCD camera, 120-min. exposure)



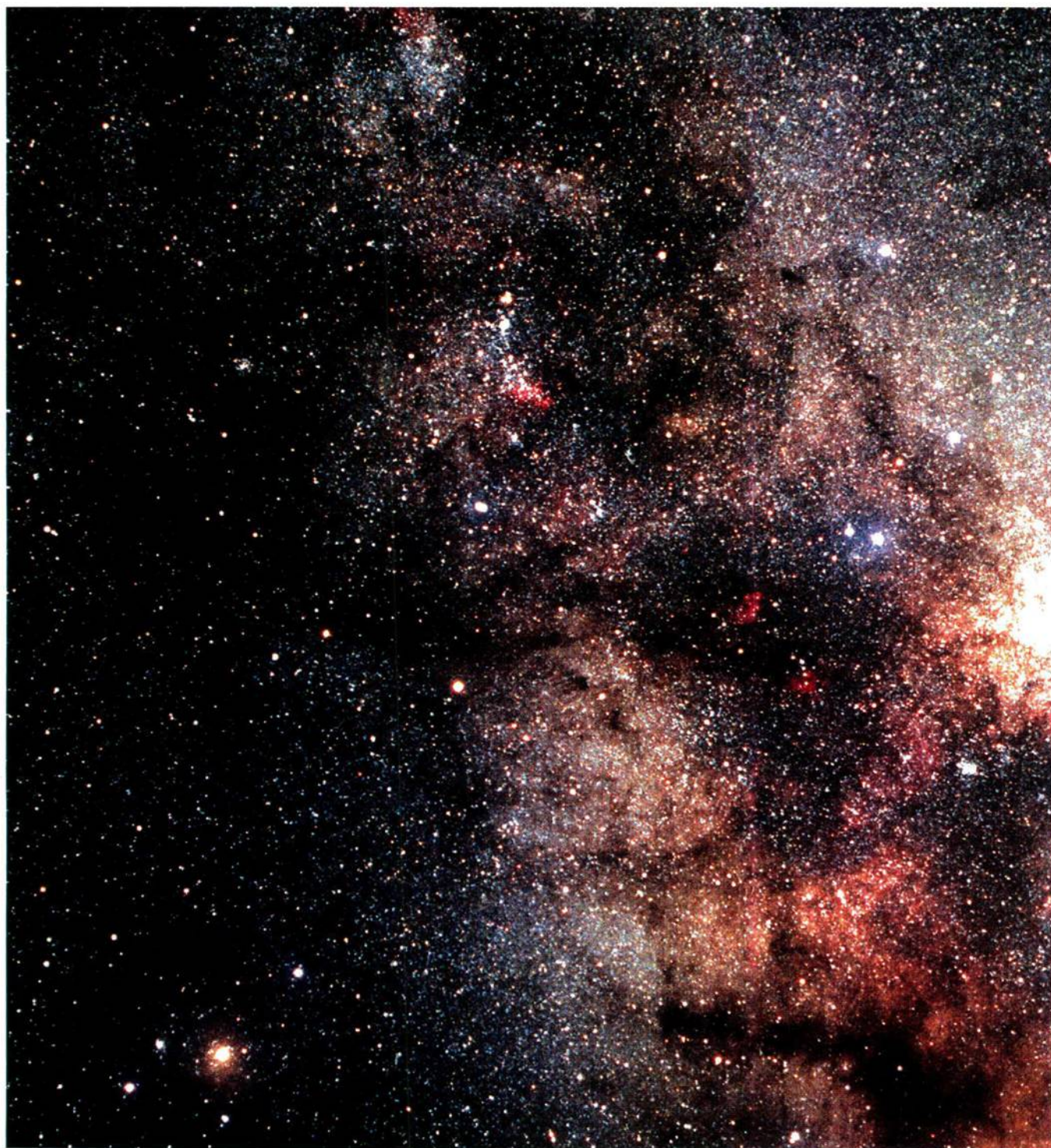
Venus Morning Conjunction

DAN OSTLER

(Canon digital camera, f/2.5, 3.2-second exposure taken July 17, 2001)



This month's best astrophoto



Milky Way Splendors in Scorpio

JOSÉ CARLOS DINIZ GONCALVES

(50mm lens at f/2.8, Kodak Supra 400 film, 20-minute exposure taken from Vicuña, Chile)

Goncalves brought out the rich colors of the Milky Way using a piggyback technique with his Nikon camera and German equatorial mount.

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